COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

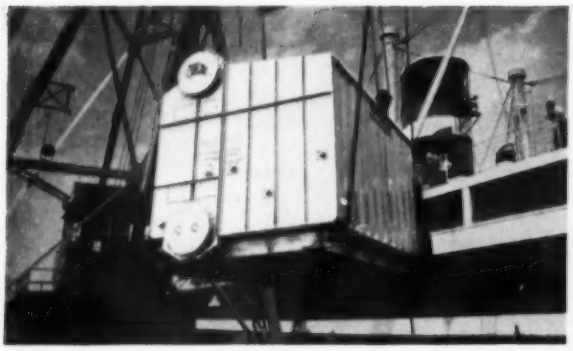
November 1959

Ground breaking for the first of two 325,000 kw units to be added to Pacific Gas and Electric Co's Pittsburg, Calif. plant in 1960 and 1961.

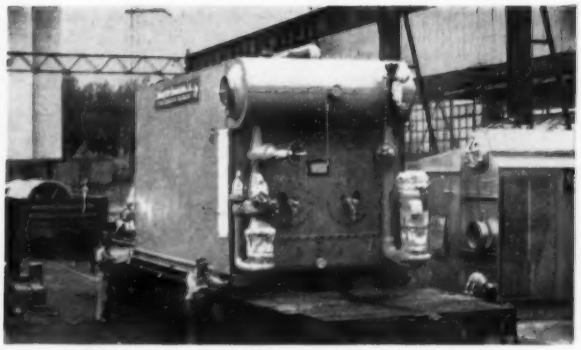
Flame Emissivity and Radiation

Vibration Cleaning Of Boilers

Viscosity of Coals



▲ A C-E Package Boiler, Type VP, en route to Europe. This boiler type is available with capacities from 4,000 to 90,000 lb of steam per hr, with pressures to 700 psi and temperatures to 750 F in certain sizes. It is designed for oil or gas firing. Several hundred of these units are now in service.



▲ A shop-assembled Controlled Circulation Boiler, Type PCC, being prepared for shipment. This type unit is available with steam capacities from 80,000 to 120,000 lb per hr, and with pressures and temperatures to 1000 psi and 900 F. For special applications, designs are available to provide higher steam pressures and temperatures. Seven PCC Boilers are now in service.

▲ A shop-assembled C-E High-Temperature Water Boiler, Type HCC, being unloaded at a midwest manufacturing plant. It is one of two 12-million-Btu boilers used for plant heating. Available for capacities from 10 million to 300 million Btu, this unit type is shop-assembled in sizes up to 50 million Btu for oil or gas firing — up to 40 million Btu for coal firing. Currently, more than 50 HCC Boilers are in service or on order.

NOW

C-E offers LARGER SHOP-ASSEMBLED BOILERS

Three service-proved designs with capacities to 120,000 lb per hr . . . pressures to 1000 psi . . . temperatures to 900 F

The economies inherent in shop-assembled boilers can now be yours even if your steam requirements are as high as 120,000 lb per hr. The C-E line, consisting of three basic unit types, has been expanded to include pressures, temperatures and capacities well beyond normal package-type limits.

The standard, natural-circulation, ***C-E Package Boiler—Type VP***—is now available with capacities to 90,000 lb per hr, and with pressures and temperatures to 700 psi and 750 F.

Where greater steaming capacity is required, or where higher pressures or temperatures are needed for industrial processing or power generation, the shop-assembled ***C-E Controlled Circulation Boiler—Type PCC***—is available. It is designed for the 80,000-to-120,000-lb capacity range, with pressures to 1000 psi and temperatures to 900 F. For special applications, this unit is also available for considerably higher pressures and temperatures.

The C-E High-Temperature Water Boiler—Type HCC—is an ideal type for large space-heating and certain process uses. It is also available in shop-assembled form for capacities to 50 million Btu per hr. It is designed for pressures to about 500 psi, and can provide water at 450 F or higher.

The new, high-capacity ranges of these shop-assembled units represent the logical evolution of familiar and successful designs that have been proved in service for quality, economy and performance.

Catalogs on any or all of these units available on request.

COMBUSTION ENGINEERING

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Canada: Combustion Engineering-Superheater Ltd.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 31 **No. 5**

November 1959

Feature Articles

Flame Emissivity and Radiation Effects from Adding Carbon Black to Liquid Fuels ..... *by E. H. Hubbard* 34

Vibration Cleaning Boiler Heating Surfaces ..... *by V. I. Chastoukhin and E. L. Zarechansky* 39

Relationship of Coal Ash Viscosity to Chemical Composition ..... *by W. L. Sage and J. B. McIlroy* 41

Steam Power Plant Clinic—Part XIII ..... *by E. K. Hess, L. E. Zabel and Igor J. Karassik* 49

20th Annual Water Conference 52

Abstracts from the Technical Press—Abroad and Domestic 57

Editorials

The Fabulous Turbo-Encabulator 33

Discussed and Disgust 33

Departments

Advertising Index 70–71

COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc. and also in the Applied Science & Technology Index.

The magazine is now reproduced and distributed to libraries on microfilm by University Microfilms of Ann Arbor, Michigan.

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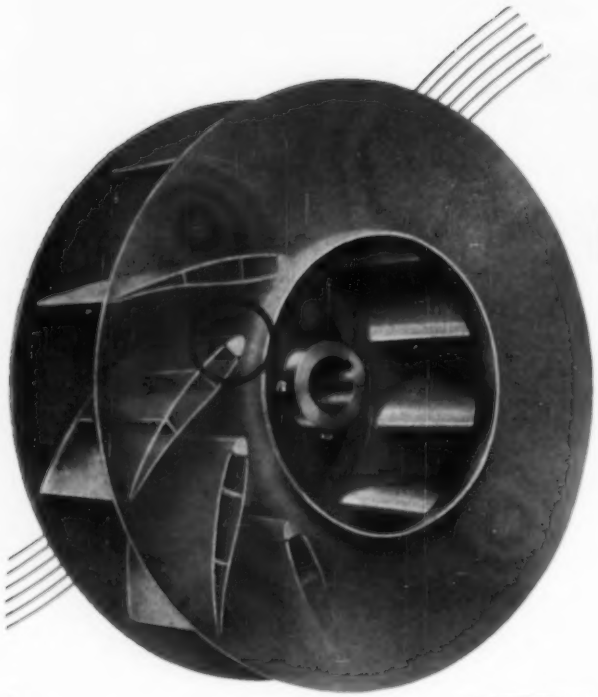
Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.
Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Thomas A. Ennis, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up; and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $5.50 in Canada, and $8 in Latin America and other countries. Single copies: Domestic, 40 cents, Foreign, 60 cents plus postage. Copyright 1959 by Combustion Publishing Company, Inc. Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P.L. & R., authorized by United States Post Office.

BPA

Printed in U. S. A.



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IN FURNACE REBUILDING

At their #2 plant in East Chicago, Indiana, Inland Steel completely rebuilt and enlarged their furnaces to increase production. These rebuilt furnaces called for greater induced draft capacity in the waste heat boilers. The old fan installation of 7 Green radial blade fans had been installed 24 years ago.

Inland Steel replaced these 7 Green fans with 7 Green AIRFOIL induced draft fans. No changes were made in the original motors or electrical system. The 7 Green AIRFOIL fans took care of the increased draft requirements without overload on the original 125 hp motors.

In short, the new Green AIRFOIL fans made it possible for Inland Steel to increase the size and capacity of their furnaces without the expense of new motors and electrical installations in addition.

The Green AIRFOIL design provides smooth airflow with a minimum of turbulence. For longer life, the AIRFOIL fan blades have specially designed cast steel nose pieces to reduce wear. (See circled nose piece in illustration.)

If you have a tough job for heavy duty fans, it makes sense to talk over your problem with Green.

Green

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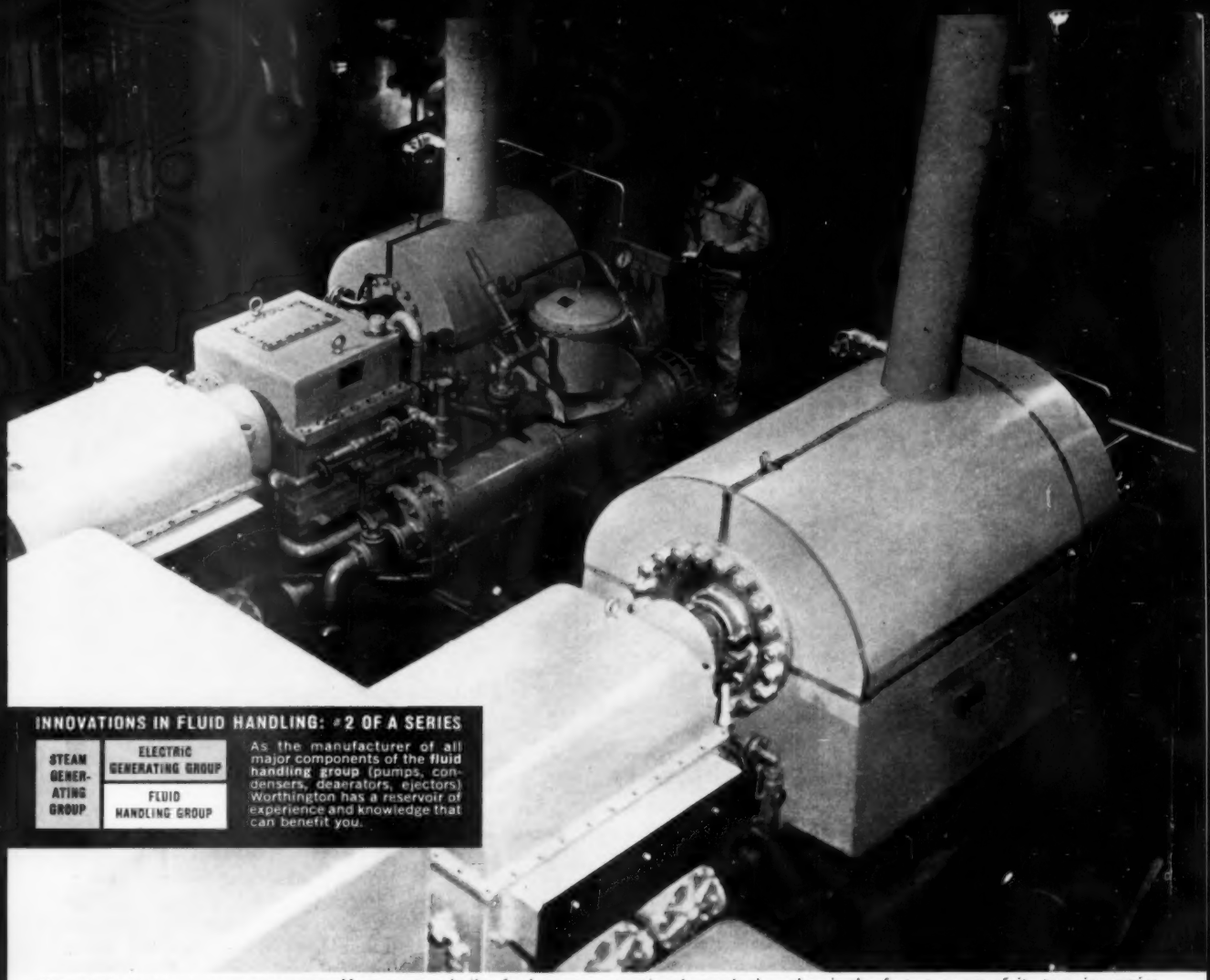
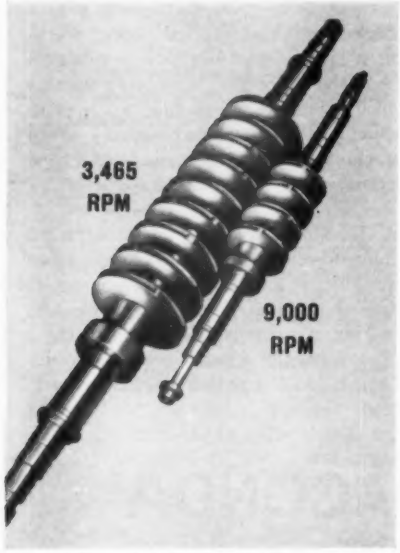
BEACON 3, NEW YORK



INNOVATIONS IN FLUID HANDLING: #2 OF A SERIES

STEAM GENERATING GROUP	ELECTRIC GENERATING GROUP	As the manufacturer of all major components of the **fluid handling group** (pumps, condensers, deaerators, ejectors) Worthington has a reservoir of experience and knowledge that can benefit you.
	FLUID HANDLING GROUP	

This photo measures pump progress. Here are two boiler feed pumps with duplicate pressure and capacity ratings. On the right is a unit of conventional speed; the other is the fastest pump of its type in service, running at 9,000 rpm. Smaller size is dramatically evident.



Comparison of rotors. The rotors used in the two pumps above are shown here. The 4-stage rotor used in the high speed pump will have one-third the deflection of the 9-stage rotor in the conventional unit.

PUMP PARADOX

High speed boiler feed pumps are several times as fast, yet actually more reliable

In modern power plants, the demand for higher efficiency has led to higher operating pressures and, therefore, higher heads for boiler feed pumps. This is a critical area for the fluid handling group. Can you obtain these higher heads without sacrificing reliability?

Worthington has proved that you can. By going to speeds twice as fast (and even greater) Worthington drastically reduces shaft spans required. This cuts shaft deflection to a fraction of its former value. Since pump wear, and hence pump life, is directly related to shaft deflection, the high speed pump is actually more reliable than a conventional unit of the same capacity.

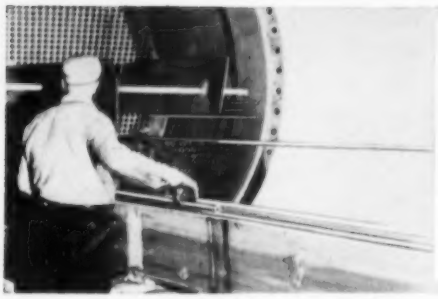
Experience in the field has proved the wisdom of Worthington's design philosophy. More than 39 Worthington high speed pumps are now installed and 21 are on order. Speeds range from 6,500 to 9,000 rpm. If necessary, Worthington sees no reason why speeds shouldn't go even higher, without departing from experience-proved construction principles.

Reducing shaft deflection through shorter shaft span is only one way that Worthington increases boiler feed pump reliability. Other ways include larger shaft diameters, liberal clearances, shrunk on impellers, metal-to-metal pressure joints, a special method for measuring internal wear, and anti-oil-whip bearings.

High speed boiler feed pumps are one example of Worthington's leadership in the fluid handling area. Through the years Worthington has made many contributions to the solution of power plant problems. Why not put this progressive "know how" to work on your next plant? Worthington Corp., Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantford, Ontario.

"45-14"

WORTHINGTON



CONDENSER AND HEAT EXCHANGER CLINIC

Edited by A. W. Tracy, Metallurgical Engineer
The American Brass Company, Waterbury, Conn.

OPERATING FACTORS THAT AFFECT CONDENSER TUBE LIFE

Answers to some of the questions sent in following a previous clinic on this subject

Q. How effective is chlorination as a preventive maintenance procedure in cleaning tubes fouled by polluted water?

A. The chlorination of polluted sea water has been found to be effective in removing or preventing the formation of slimes on the walls of tubes. Better cleanliness was indicated by higher vacuum obtained on the steam side of the condenser. Tubes kept clean by chlorination have been reported to be less subject to pitting. It should be interjected here that tubes carrying polluted sea water containing sulfides from decomposition of organic matter seldom undergo inlet end corrosion, but the remainder of the length of the tubes often becomes pitted. Clean sea water, if entering the tube turbulently, will often cause corrosion at the inlet end, and usually the remainder of the length of the tube is coated with a good protective film of corrosion products.

The statement that chlorination may break down sulfide films on the walls of tubes is based on the fact that chlorine is an oxidizing agent and would oxidize sulfides; however, it is realized that the usual chlorine treatment would probably not remove thick long-standing sulfide scales.

Q. How often should tubes be cleaned and what are some of the methods used?

A. The required frequency of tube cleaning depends, of course, on how rapidly the tubes become fouled. In some power plants, tubes are cleaned once a week; at other stations, cleaning is required only at intervals of several months. Often the decision to clean tubes is determined by the drop in vacuum on the steam side.

In regard to methods for removing accumulations from condenser tubes, some station operators shoot rubber plugs through the tubes; others use bristle brushes, either of animal hair or nylon. The use of brushes is reported by some to do a better job of cleaning than the use of plugs.

An interesting method for continuously cleaning condenser tubes has been developed in Europe. A large number of sponge rubber balls, slightly larger in diameter than the inner diameter of the tubes and having about the same specific gravity as sea water, is fed continuously into the inlet water box. The cooling water forces the balls through the tubes, and deposits on the tube walls are swept away. The balls are collected by a cone in the outlet water box. They leave the water box through a tube connected to the end of the cone and are recirculated into the inlet water box. By the law of probability, each tube will eventually receive a ball. The system is not applicable to tubes that have been in service and have become rough and pitted.

Some stations periodically remove deposits from tubes by recirculating a dilute, inhibited hydrochloric acid solution through the condenser.

Q. How important are temperature and velocity as factors in the service life of condenser tubes?

A. Corrosion of condenser tubes is usually more rapid in summer than in the winter, but pollution due to bacterial action in the summer may be a more important factor than temperature itself. Instances have been observed where failures in a set of tubes occurred only in the warm-water months and none in the cold-water months, over a period of several years.

Mention was made in the clinic to the effect that high temperature of water causes pitting, due to the formation of gas bubbles on the tube wall. This type of pitting occurs most frequently, but not often, in oil refinery condensers where temperatures on the vapor side may be as high as 350F and water velocities relatively low. In a power plant condenser, temperatures on the vapor side ordinarily do not exceed 100F and temperature rise in the cooling water from the inlet to the outlet end is usually limited to 10F.

TECHNICAL ASSISTANCE. Our Metallurgical Department is regularly helping manufacturers, electric power companies, marine operators, petroleum and chemical companies to select the correct tube alloy for many types of condensers and heat exchangers. This service is available to you without obligation. Write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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FOR CONDENSERS AND HEAT EXCHANGERS

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Yarway Integral Strainer Impulse Steam Traps drain some of the hottest steam lines in the country, with temperatures to 1050°F and pressures as high as 2500 psi.

These traps have ample capacity when system is being warmed up, yet handle relatively small amounts of condensate without losing prime. In the presence of dry or superheated steam, the trap valve snaps shut.

Utilities and other high pressure plants also benefit from further advantages like *small size, light weight, steel construction, easy maintenance.* Available in six sizes, flanged or welding ends.

Over 1,250,000 Yarways already sold. For full information, call your local Yarway Representative or write

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SERIES 60—normal needs, pressures to 400 psi, 6 sizes. **SERIES 120**—normal needs, pressures to 600 psi, 6 sizes. **SERIES 40**—for extra heavy loads, 5 sizes. **NO. 30**—for extra light loads (½" only). **INTEGRAL STRAINER**—highest pressures and marine use, 6 sizes.

YARWAY *impulse steam traps*

Once in a while...

something big comes along. Maybe it's a piece of wood or ball of pyrites or a chunk of frozen coal. Even in the best managed plants it happens occasionally. When it does, you have a right to expect the feeders to your pulverizers or cyclone burners not to plug or jam.

S-E-Co. *Volumetric Feeders* and S-E-Co. *Gravimetric Feeders* are built to assure reliable operation no matter what comes along. The full 24" width of coal stream from inlet through to outlet and the fact that the coal is carried on a heavy duty belt contribute to this ability. The samples of frozen coal, wood, and pyrites you see on the opposite page are just a some of the oversized objects that have come through S-E-Co. feeders without interrupting the flow of coal.

Of course you don't want to feed your pulverizers or cyclones a steady diet of wood and pyrites. What you do want is a steady, well controlled flow of coal. Even fine, wet, sticky coal is duck soup for S-E-Co. feeders.

In your next boiler specification include
S-E-Co. Volumetric or Gravimetric Feeders

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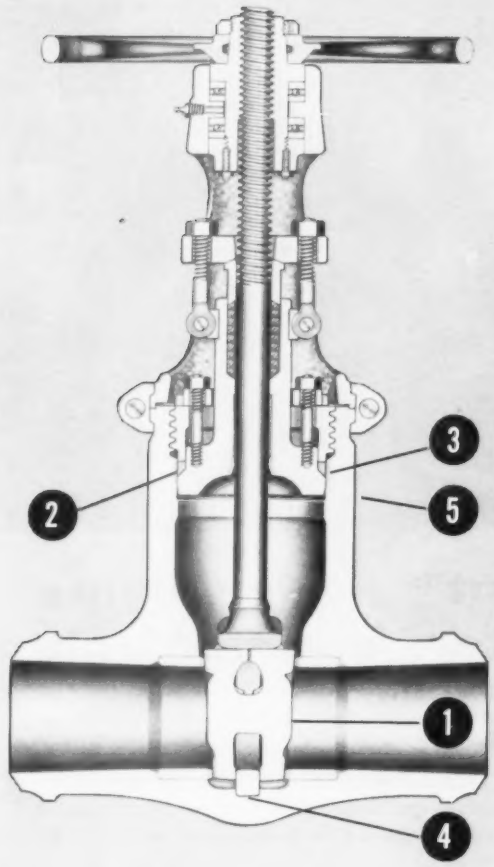

Pressure-seal bonnet gate valves: 1" to 24"; 600-, 900-, 1500- and 2500-pound classes. Flanged, socket-, or butt-welding ends.

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❶ Flexible wedge disc prevents sticking.

❷ One-piece, silver-plated seal ring remains freeze-free for easy dismantling.

❸ Wear-resisting stainless steel inlay prevents corrosion at this critical point.

❹ Full-length disc guides prevent wear and drag on seating surface.

❺ Design saves up to 60% of weight of bolted bonnet valves.

ALL CRANE PRESSURE-SEAL BONNET VALVES ARE ASA-RATED

Minimum metal thicknesses comply fully with the requirements of ASA B16.5-1957 as well as ASA Code for Pressure Piping and ASME Boiler and Pressure Vessel Code.

New globe lift-checks. Feature only two internal parts: cage-type disc and liner. 900-pound class, 3" to 12"; 1500-pound class, 2½" to 12"; butt-welding ends. Stop-checks available also.

Globe and angle valves. Globe valves of Y-pattern design in all sizes; interior areas shaped to decrease turbulence, reduce pressure drop. 1" to 16"; 1500-pound class; socket- and butt-welding ends.

Modern controls for steam stations...
Crane pressure-seal bonnet gate valves

Here is the most modern valve designed for high-pressure/high-temperature service. Bonnet joint leakage is eliminated. Weight is reduced without sacrificing strength and safety. Its streamlined contour simplifies insulation. Easy accessibility provides for quick, in-line servicing. Critical points of wear are protected by special metals. These and other advantages assure trouble-free service with minimum maintenance.

For complete facts about this gate valve and all other valves in the *expanded and improved line* of Crane valves for power plant service, see your Crane Representative.

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PIPE • PLUMBING • HEATING • AIR CONDITIONING

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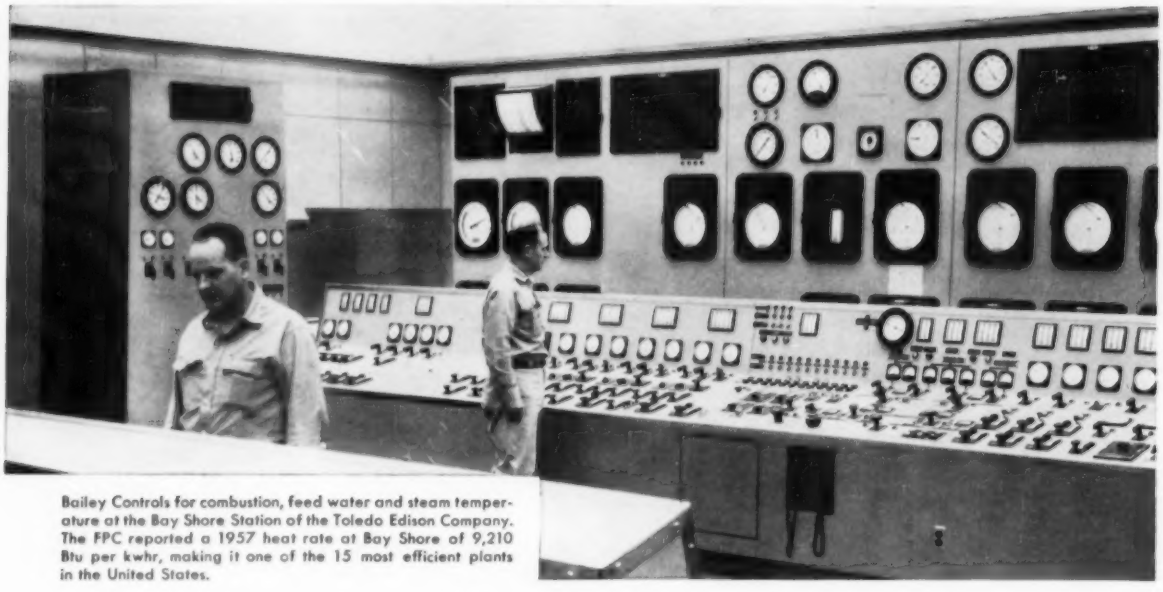

Bailey Controls for combustion, feed water and steam temperature at the Bay Shore Station of the Toledo Edison Company. The FPC reported a 1957 heat rate at Bay Shore of 9,210 Btu per kwhr, making it one of the 15 most efficient plants in the United States.

13 of 15 "most efficient"* power plants depend on Bailey Meters and Controls

Year after year you'll find Bailey Meters and Controls keeping sensitive fingers on the pulse of America's *most efficient* power plants (as rated by the Federal Power Commission.

According to the latest box scores, 10 of the top 15 used Bailey equipment exclusively. There must be a reason. There is! In fact, several:

1. Experience—Bailey Engineers have been making steam plants operate efficiently for more than forty years. They bring you the latest, up-to-the-minute developments in measurement and control.

2. Complete Line—Bailey manufactures a complete line of pneumatic and electric metering and control equipment, proved on thousands of successful installations.

3. Sales and Service—There's a Bailey District Office or Resident Engineer close to you (listed under Bailey Meter Co. in your phone book). Phone for expert engineering counsel.

* 15 MOST EFFICIENT PLANTS • 1957 Heat Rates Reported by the Federal Power Commission

	Btu/kwhr	Meters	Comb. Control	Feed Water Control	Supht. Control
1. Kanawha River (Appalachian Electric Power Co.)	9,118	B	B	B	B
2. Muskingum River (The Ohio Power Co.)	9,139	B	B	B	B
3. River Rouge (The Detroit Edison Co.)	9,140	—	—	—	—
4. Clifty Creek (Indiana-Kentucky Electric Co.)	9,147	B	B	B	B
5. Tanners Creek (Indiana and Michigan Electric Co.)	9,180	B	B	B	B
6. Kyger Creek (The Ohio Valley Electric Corp.)	9,201	B	—	B	B
7. St. Clair (The Detroit Edison Co.)	9,210	B	B	B	B
8. Bay Shore (The Toledo Edison Co.)	9,210	B	B	B	B
9. G. G. Allen (Duke Power Co.)	9,349	B	B	B	B
10. John Sevier (Tennessee Valley Authority)	9,350	—	—	—	—
11. Phillip Sporn (Central Operating Co.)	9,370	B	B	B	B
12. Milliken (New York State Electric and Gas Co.)	9,371	B	—	B	—
13. Shawville (Pennsylvania Electric Co.)	9,396	B	—	—	B
14. El Segundo (Southern California Edison Co.)	9,467	B	B	B	B
15. Colbert (Tennessee Valley Authority)	9,490	B	B	B	B

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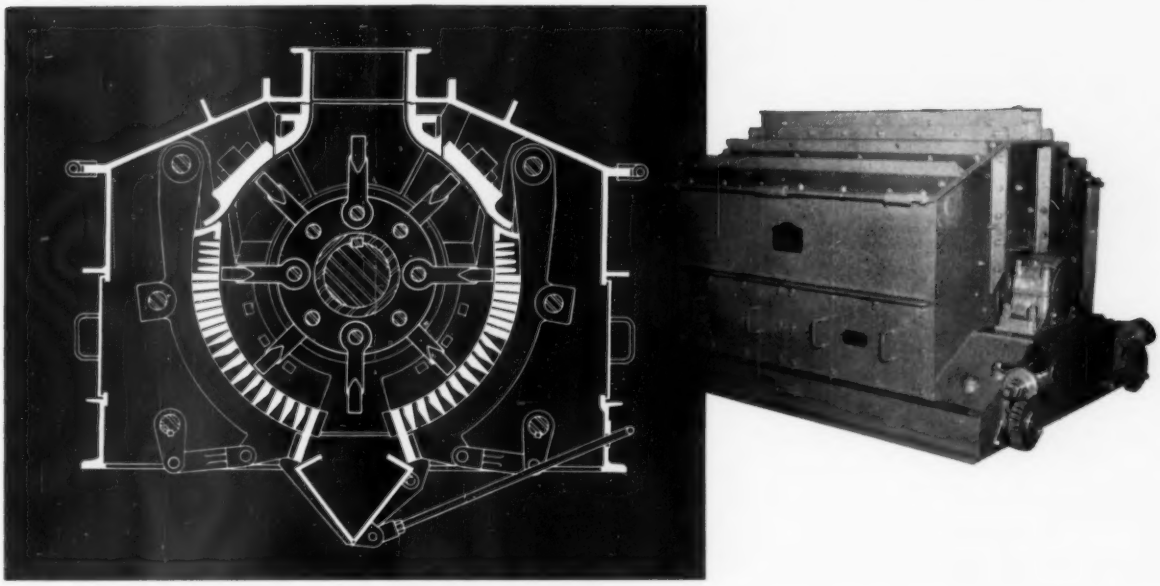

Here's how the Pennsylvania Reversible Hammermill will help lower your operating costs

As the coal enters the mill it is precrushed in the upper zone by being struck by the hammers in free air, driven against the breaker blocks, ricocheting and struck by hammers again. Only small lumps enter the lower crushing zone for final reduction before escaping through the cage bars. There's no dragging of hammers through oversize in the lower crushing zone. Thus wasteful fines are held to a minimum along with hammer wear and power requirement. The easily adjusted cages assure you a uniform product for the life of the hammers regardless of variance of the physical properties of the coal. The cage adjustment also permits you to wear the hammers much further, and, due to reversibility of the rotor, there is no manual turning of the hammers. Get the complete story of these crushers. Send for bulletin 1040. Pennsylvania Crusher Division, Bath Iron Works Corporation, West Chester, Penna.

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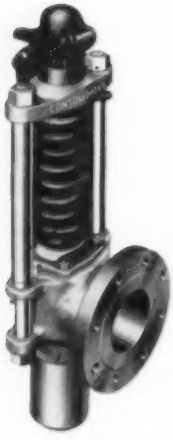
STOPS VALVE LEAKAGE

at high pressures



Consolidated "Maxiflow" Safety Valve, Type 1700 Series, Sizes: 1½" thru 6".

The Thermodisc Seat in Consolidated "Maxiflow" Safety Valves solves the problem of valve leakage at high pressures, saves steam and reduces maintenance.

Research has shown that when a safety valve on high pressure service reseats after popping, a small amount of leakage occurs momentarily between seat and disc before the valve seals off and becomes tight. This leakage is comparable to steam flow through small, individual orifices.

When a small steam leak exists at some point on the valve seat, the area near the point is cooled by the refrigeration effect of the escaping vapor. The metal tends to contract causing slight deformation of the seat. This acts to increase the gap size between disc and seat bushing at the leakage point. The size of the gap increases rapidly until the rate of leakage becomes extremely high.

The Thermodisc Seat prevents seat distortion and consequent leakage with a seat element recessed to form a thin wall at the area of seat contact. This design permits a high rate of heat-transfer in the metal *that eliminates all thermal differences.*

The result is a degree of tightness, essential to the operation of safety valves in high pressure services, never previously achieved. For complete details, write for Bulletin 707B.

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Long a leader in the application of the newer alloys, and in the development of better welding materials and welding techniques for the power generating industry, Kellogg is today privileged to announce more than a dozen projects concurrently executed with the *five* major utilities, listed above. Each of these major assignments includes the use of Kellogg's K-Weld® technique for welding the main steam and other critical lines, both in field erection and shop fabrication.

Kellogg welcomes inquiries on its complete fabrication and erection service to the power piping industry from consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

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AT F.M. TAIT STATION, DAYTON POWER & LIGHT CO.

BOILER CLEANING IMPROVEMENT HELPS MODERNIZATION PROGRAM

SAVE $40,000

DIAMOND BLOWERS and AUTOMATIC

Three of the Diamond Model IK Long Retracting Blowers installed to replace manually operated rotary blowers. Electric motor driven, they are controlled by the Automatic Sequential Panel. Air is used as the blowing medium. Rotary elements were retained in cooler locations and motorized for automatic operation and are also controlled by the Automatic Sequential Panel.

In the continuous struggle to cut operating costs, the Dayton Power & Light Co. has found a very useful tool in "Boiler Cleaning Modernization."

By applying the latest soot blowing equipment to four of their boilers at the F. M. Tait Station, together with other features of the modernization program, the Dayton Power & Light Co. was able to reduce the operating costs on these boilers by some $40,000 per year and also cut blower maintenance costs.

On the first boiler that had its cleaning modernized, 17 rotating elements were removed; the remaining seven blowers of this type were electrified for automatic control. The cleaning equipment added consisted of five Long Retracting Blowers and six Short Retracting Blowers. All blowers are automatically controlled by a Diamond Selectromatic Panel.

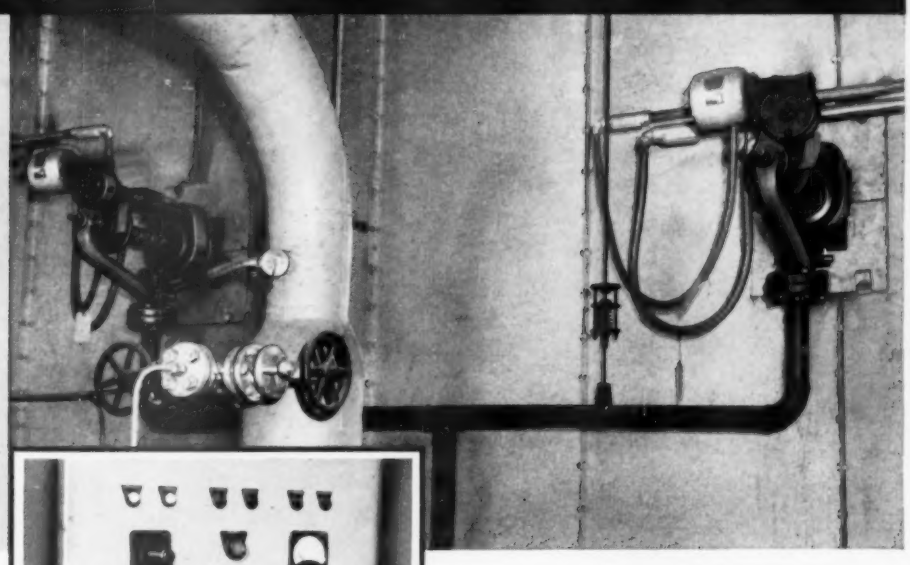
This is one of many examples of the savings possible by improvements now available in Diamond Blowers and Automatic Sequential Control. Over the years Diamond has engaged in continuous aggressive research in boiler cleaning. This research has paid off in improvements that save you money and improve your operation.

Let us make a study of your boiler cleaning . . . perhaps similar savings can be suggested.

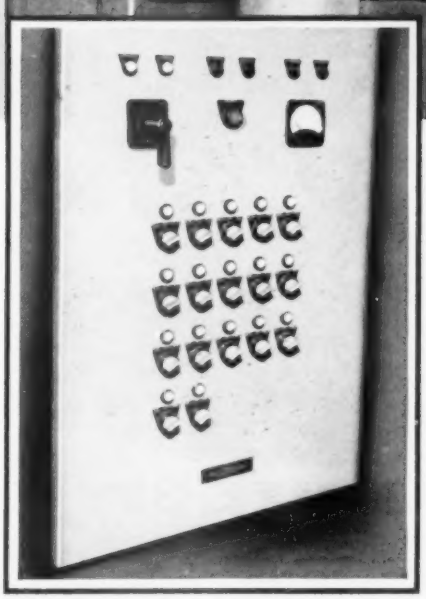
Per Year in Operation

and Cut Blower Maintenance Costs

SEQUENTIAL CONTROL PANEL



Two of the air blowing Model IR short retracting wall blowers with electric automatic operation.



Diamond Automatic Sequential Control Panel installed as part of the modernization program at the F. M. Tait Station. This panel automatically operates each blower in turn until the blowing cycle is complete. Any individual blower may be operated independently by simple turning switches. Cleaning program is set up by switches. Operator starts — thenceforth operation is automatic.

DIAMOND POWER SPECIALTY CORP.

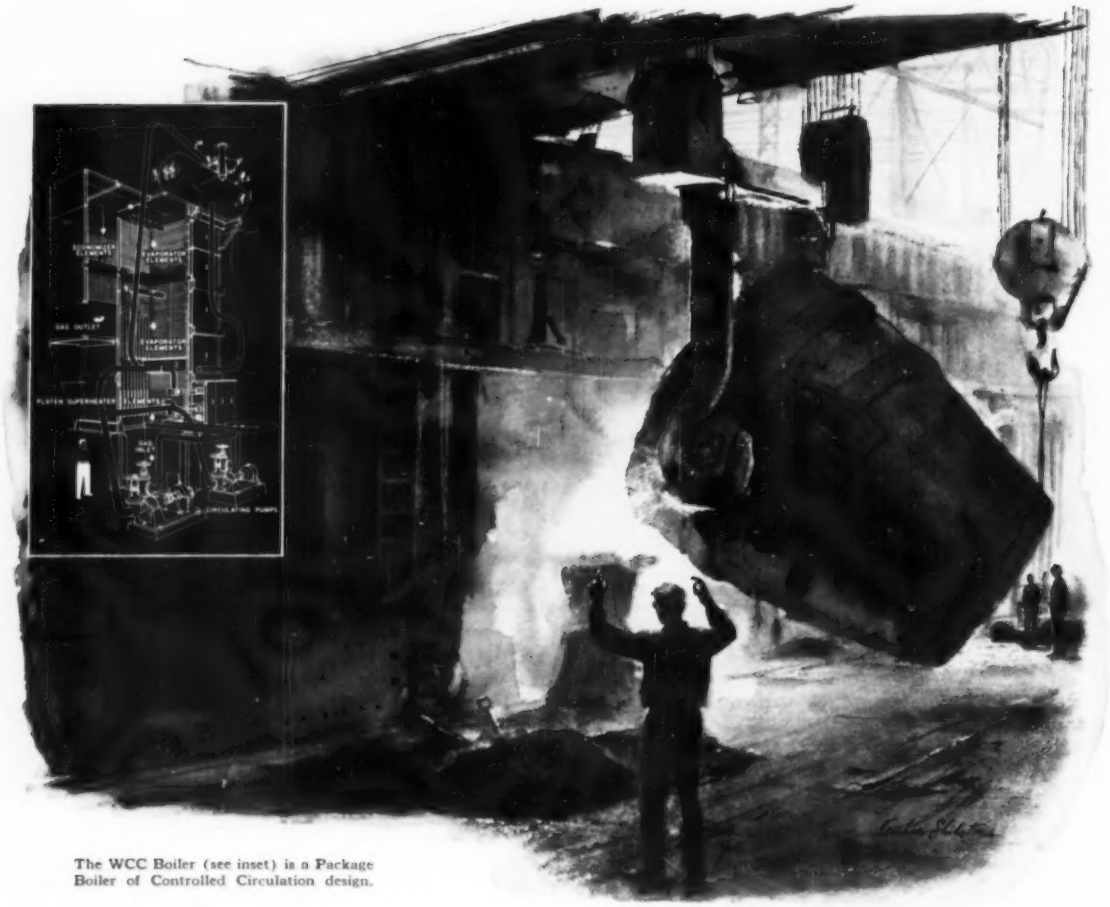
LANCASTER, OHIO

6243

DIAMOND SPECIALTY LIMITED • WINDSOR, ONTARIO

WASTE HEAT AND BY-PRODUCT STEAM WHEN

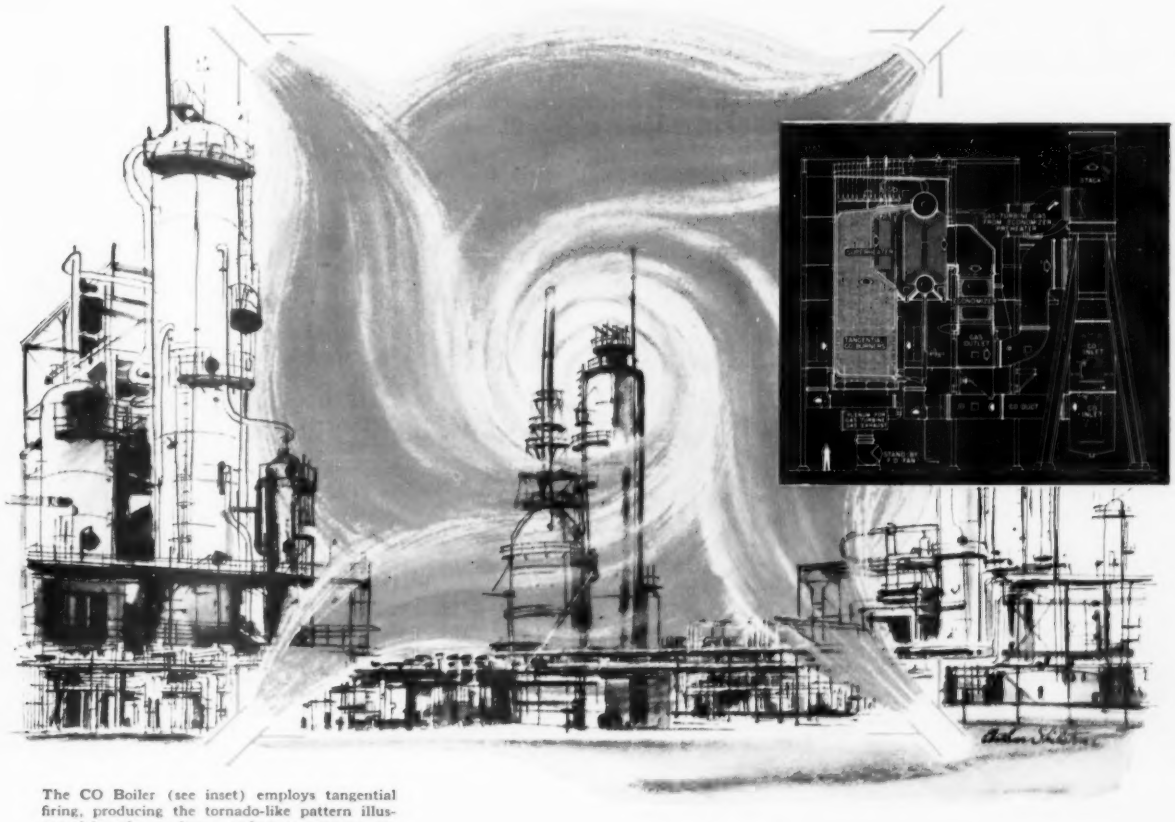
Though no two industrial processes are exactly alike, a great many produce hot waste gases or by-product waste materials. Often, they contain substantial amounts of energy which, when properly used, can provide a valuable addition to the fuel supply of a plant. C-E has had long and varied experience in taming and harnessing many kinds of waste and marginal fuels. At the steel mill pictured below and in refineries like the one at right, C-E boilers use just such fuels to provide dependable, low-cost steam.



The WCC Boiler (see inset) is a Package Boiler of Controlled Circulation design.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT, NUCLEAR REACTORS

MATERIALS PROVIDE LOW-COST HARNESSED BY C-E



The CO Boiler (see inset) employs tangential firing, producing the tornado-like pattern illustrated in color, to burn catalyst regenerator gas.

As discussed on the opposite page, two interesting examples of waste heat "in harness" are the applications of specially designed C-E boilers to the exhaust of steel mill open hearth furnaces and to the catalyst regenerator exhaust of a refinery. In each case, the gases used are peculiar to the industry involved. In one instance, they are sticky and corrosive and offer only sensible heat. In the other, the gases are toxic and moist, and contain a lean measure of chemical heat in the form of carbon monoxide—in addition to sensible heat. In both cases, C-E advanced engineering has created boiler designs (see sketches) ideally suited to the heat source—boilers which provide maximum steaming capacity with minimum maintenance. Other C-E boiler designs in the waste heat category are in service using a wide variety of waste process gases — with and without chemical heat. In the area of marginal and by-product fuels, C-E has designed and placed in service a large number of boilers which burn such wastes as refinery sludge, wood shavings, sawdust, pith, rice and oat hulls, furfural waste, bagasse, peanut shells, grape skins, spent coffee grounds, black liquor and, of course, coke oven and blast furnace gas.

What all this adds up to is the fact that there is really no such thing as waste heat—there is only *wasted* heat. And there needn't be—because Combustion has the know-how and experience to put almost any potential energy source to work for you—to provide you with an extra dividend in the form of additional low-cost steam for your plant. Why not investigate harnessing a C-E boiler to your waste heat or by-product material? The amount of money it can save for you may be surprising.

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N.Y.

C-227

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

Hall Industrial Water Report

VOLUME 7 NOVEMBER 1959 NUMBER 6

How Will It Come Out?

Industrial water softeners of many types are daily turning out millions of gallons of treated boiler feedwater. Usually the softener effluents are of good quality, meeting chemical specifications and suitable for the intended use. But things can go wrong both mechanically and chemically, and close control is essential to make sure the water "will come out all right."

Hall Laboratories engineers are thoroughly familiar with water softening procedures and equipment. They can serve you not only in setting up, but also in maintaining the routine control necessary to make your equipment operate efficiently. And they can help you determine the cause of trouble when, for no obvious reason, effluent quality is poor.

Coagulant Aid Helps Softening

The hot lime soda—hot zeolite water softener at a western paper mill functioned satisfactorily until demand pushed flow rate up to and beyond the capacity of the unit. Then more sludge was carried out of the sedimentation tank in the lime soda-treated water than the filters could handle. Some went on to the hot zeolite softeners, seriously fouling the ion exchange material. Excessive backwashing was necessary.

Hall engineer L. Arnold considered how he might hasten settling of precipitated sludge in the sedimentation tank. He recommended the use of a Hagan coagulant aid because this represented the quickest and probably most effective move.

Results were impressive. Soon after the aid was added to the lime and soda ash chemical tank the settled water cleared up. The plant operators enthusiastically pointed out that there was less suspended material in the water going to the filters than there had been previously in the effluent coming out of them.

Hardening Condensate

An automobile parts manufacturing plant prepares boiler feedwater in a hot-process softener. There are two sections in the equipment, one for deaeration of condensate and one for heating and lime-soda softening of makeup. The softened water is filtered and combined with the deaerated condensate.

The operators watched water conditions carefully and operated without trouble for some time. Then one day they were puzzled by unprecedented difficulty in maintaining reserve phosphate in the boiler water. Wishing to solve the problem as quickly as possible they called Hall engineer D. W. Whiteside.

When Whiteside arrived at the plant the operators reported to him their observation that the normally clear boiler feedwater was turbid. The turbidity was quickly determined to be sludge from the softening section of the hot process unit. Further checking showed that the sludge was in the deaerated condensate while the treated, filtered makeup water was clear.

Now it was obvious that something was wrong inside the softener, permitting treated water from the softening section to get into the condensate section. Subsequent inspection revealed partial plugging of the downflow pipe through which treated water flowed from the primary softening zone to the settling chamber. Water level rose high enough in the primary softening zone to spill the treated water over the baffle separating this from the condensate section.

A good cleaning of the downflow pipe corrected the trouble. Routine cleaning during regularly scheduled shutdowns was established to avoid future difficulty.

Care of Ion Exchange Resins

Exchange resins are expensive. A running check on performance is important in setting up cleaning and replacement programs which assure maximum useful life and put replacement cost on a uniform annual basis thus avoiding sudden major replacement expenditures.

Plant operators should carefully watch the relationship between raw water composition and gallons of water treated between regenerations of cation exchangers. A noticeable drop in capacity can give early warning of the need for cleaning.

Gradual increase in pressure drop across a cation bed is an indication that the material is becoming dirty or is starting to break down. This information should be used in conjunction with service capacity data to check condition of the resin.

Crosslinkage checks are desirable about once per year for small cation units and twice per year for large units. If caught in time, breakdown can sometimes be retarded by treatment of the water with sodium sulfite or sulfur dioxide.

The condition of anion exchange material is best watched by observing the amount of dissolved solids removed per cubic foot of resin per cycle.

Rinse requirement is important too. Increase often means deterioration or fouling. The observations may be used alone or together to determine the need for cleaning or replacement.

Hall engineers can help you set up and maintain routine testing and regeneration programs as well as the longer term checks on performance. Furthermore, Hall Laboratories is well equipped and staffed to do special work on resin capacity, crosslinkage and experimental cleaning.

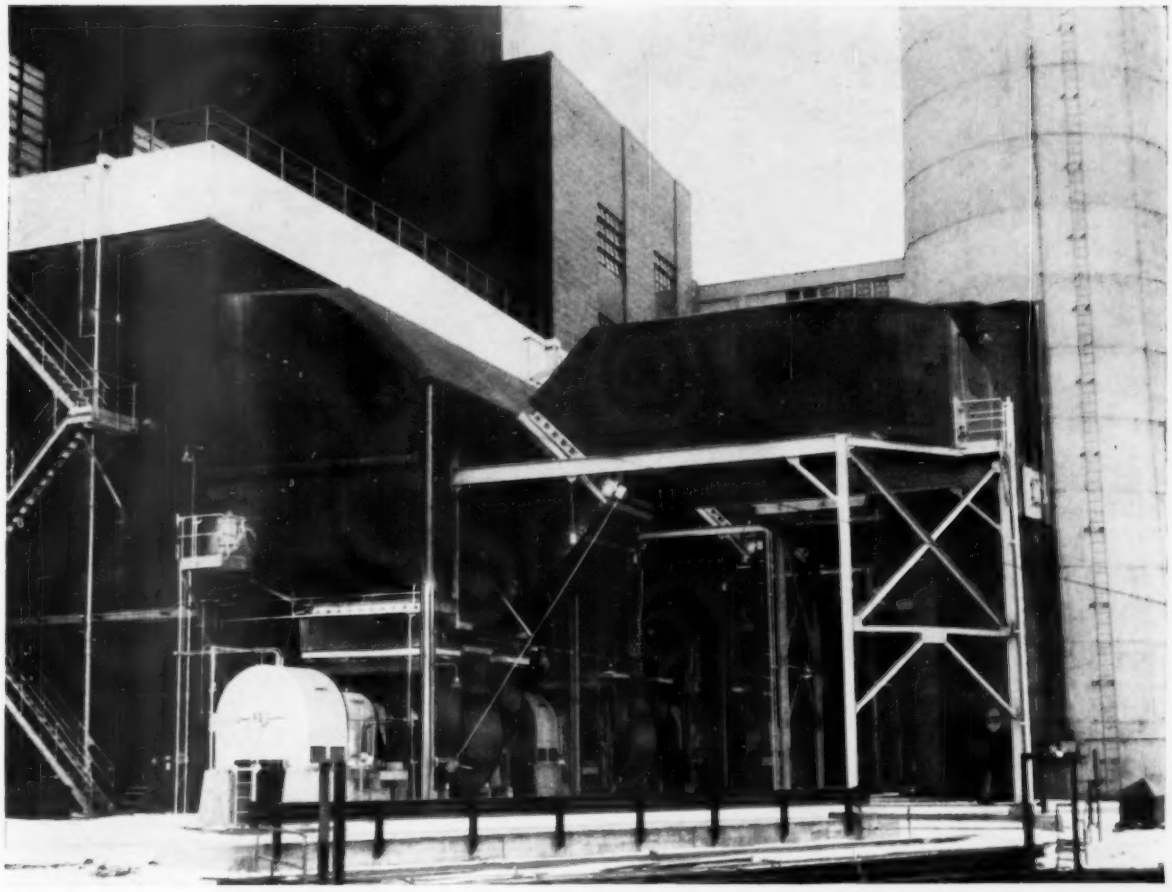
Water is your industry's most important raw material. Use it wisely.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information on how the Hall System can help you solve your particular water problems, write, wire or call address below.

HALL LABORATORIES
DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PA.
In Canada: Hagan Corporation (Canada) Limited, Toronto

Hall Laboratories—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water



"Buffalo" Induced Draft Fans at Commonwealth Edison Company's Waukegan Station, Unit 7. Fans draw from a common precipitator plenum chamber and discharge into a common stack. Fans deliver 312,000 cfm at 21" S.P. at 300° F., have air cooled bearings. Engineered by Sargent and Lundy.

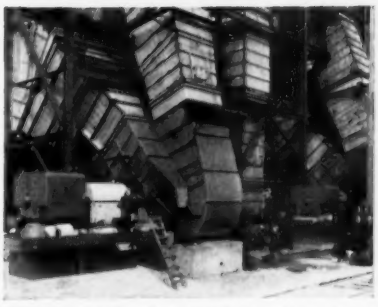
COMMONWEALTH EDISON COMPANY SELECTS "BUFFALO" FOR INDUCED DRAFT

The Commonwealth Edison Company has, over the years, purchased numerous "Buffalo" fans. This is a tribute to the performance, quality and long service life of "Buffalo" Products.

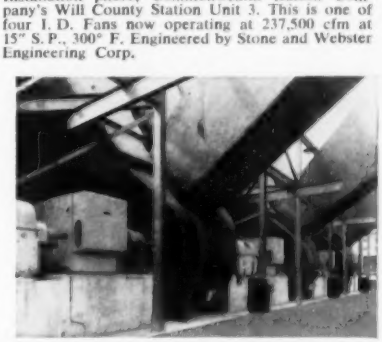
This same reliable performance and "Q" Factor Quality Construction is available to you in every "Buffalo" fan.

You are assured of getting the right fan for every job, too, since "Buffalo" offers a complete line of fan wheel types, each suited to a different set of circumstances.

The next time you need fans for any installation, large or small, be sure to phone your "Buffalo" Engineering Representative. He will have the best fan for the job and the experience necessary to see that it is recommended.



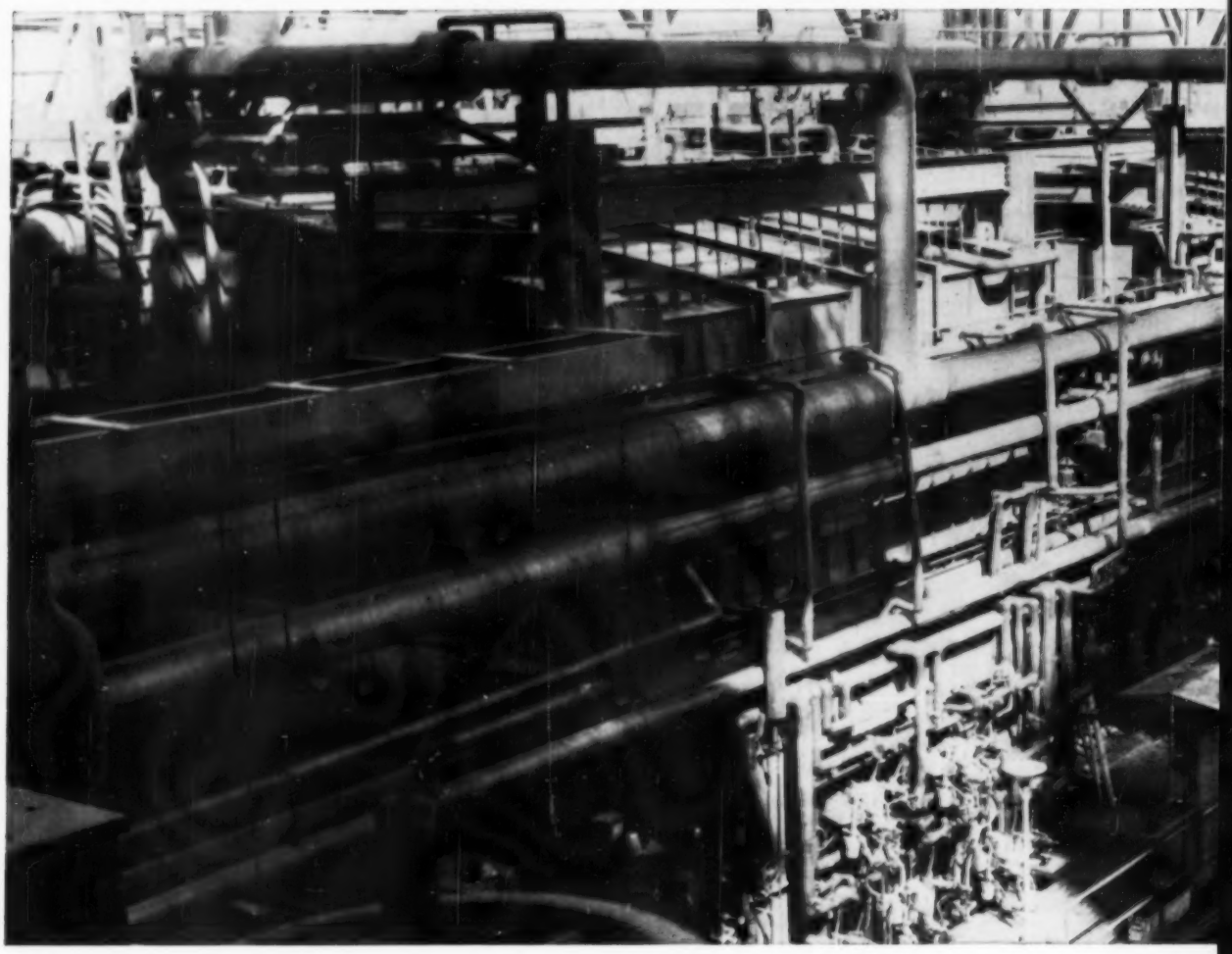
Installation photo, Commonwealth Edison Company's Will County Station Unit 3. This is one of four I. D. Fans now operating at 237,500 cfm at 15" S. P., 300° F. Engineered by Stone and Webster Engineering Corp.



Construction photo showing three of the four "Buffalo" I. D. fans at Commonwealth Edison Company's Fisk Street Station. These fans are now each operating at 362,300 cfm at 23.2" S.P., 325° F. Engineered by Bechtel Corp.

BUFFALO FORGE COMPANY
Buffalo, N. Y.
Buffalo Pumps Division Buffalo, N. Y.
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING
FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING



Copes-Vulcan boiler control load conditions at Deepwater

In addition to producing power for the Atlantic City Electric Company system, the Deepwater plant delivers steam to an adjacent chemical plant for process use.

To meet the widely fluctuating process demands, Copes-Vulcan controls the two low pressure boilers with precision responsiveness. Each boiler has a maximum continuous rating of 150,000 pounds per hour at 230 psig saturated. The system consists of:

Combustion Control maintaining a constant pressure in the main process steam header by holding steam output from the boiler equal to steam demand.

Copes-Type 3-L Feedwater Control modulated by three control influences—steam flow, feedwater flow and drum water level.

Boiler feed pump recirculation control protecting the boiler feed pumps against overheating on light loads.

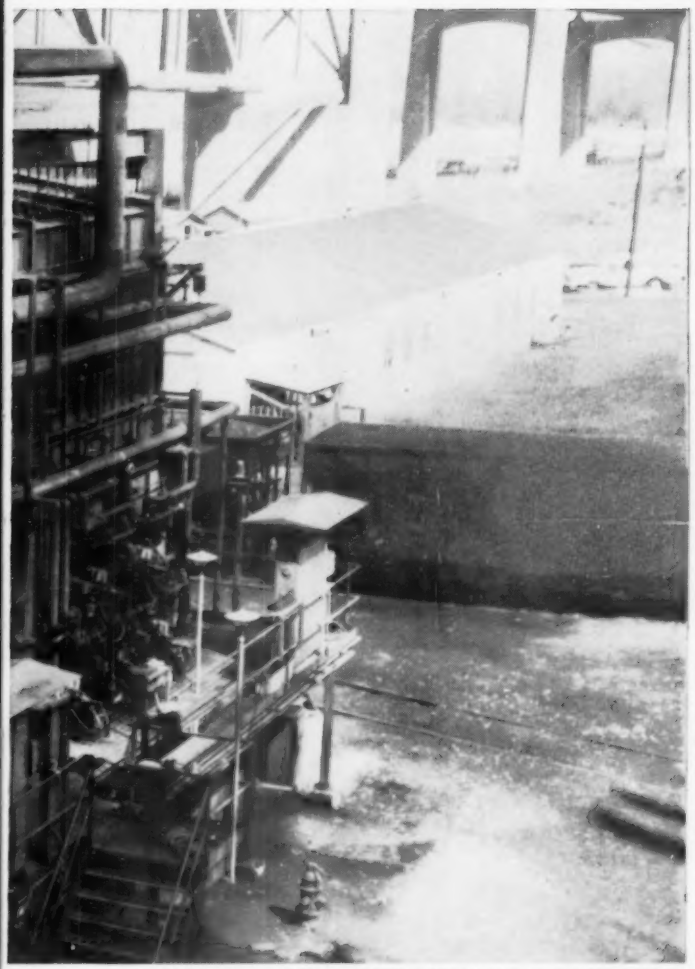
Vulcan Rotary Soot Blowers providing positive cleaning over the full blower arc, which may be as much as 360 degrees.

The system controls all equipment with either one or two boilers in service, permits each boiler to carry a different load. Control is automatic through a load range of 20,000 to 200,000 pounds per hour.

Whether your boiler is large or small, power or process, Copes-Vulcan can provide a unit or an integrated package, custom designed to your requirements. **For details on the Deepwater Station installation, write for Bulletin 1057.**

Copes-Vulcan Division
BLAW-KNOX COMPANY • Erie 4, Pennsylvania

BLAW-KNOX



Outside boilers and boiler controls subject to severe weather, with temperatures as low as 10° F. Except for the central control panel and relays and controllers mounted on it, the Copes-Vulcan control system is entirely outdoors.

meets unusual

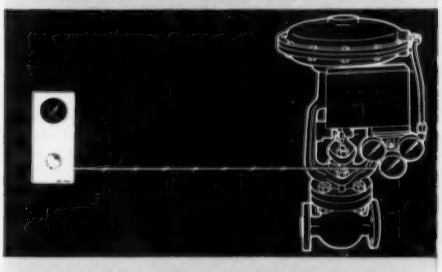
Station

Diaphragm-operated CV-D valve controls the speed of the turbine driving the forced-draft fan. Copes-Vulcan also makes piston-actuated valves. Both types meet pressure standards of 125 to 2500 pounds.

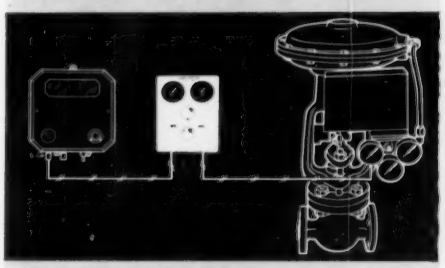
The drive unit with positioner, 4-way valve, power piston and feedback cam controls forced-draft damper. C-V drive units permit remote positioning by automatic or manual pneumatic signals.

C-V NEWS NOTES

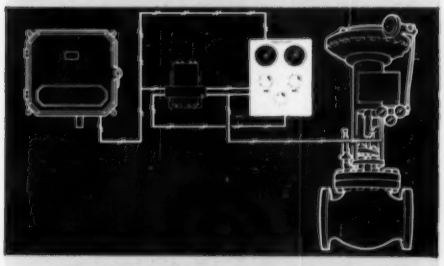
PNEUMATIC CONTROL STATIONS



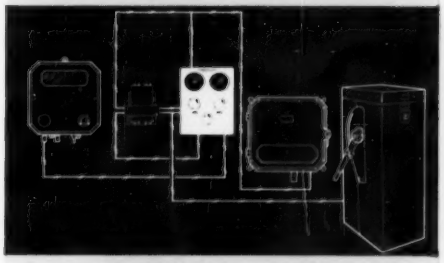
Copes-Vulcan stations offer automatic-to-manual selection without the complication of seal balance. They indicate process-variable, controller and manual loadings. Transfer is "bumpless" without process disturbance. Shown above: the ML-4 Manual Loading Station.



AM-4 Selector Station . . . indicates an automatic loading—or originates a manual loading—to the valve, power cylinder or other control element.

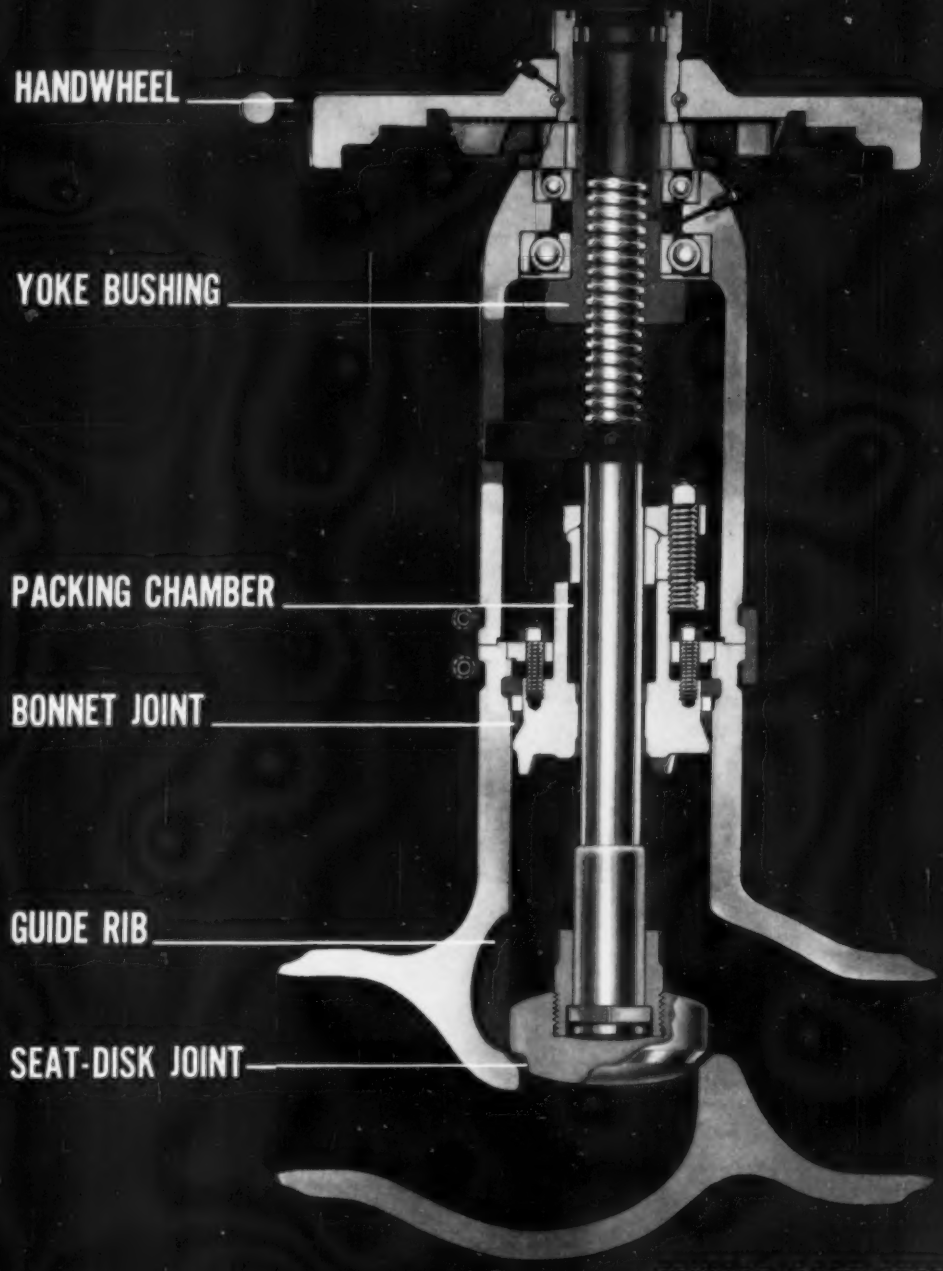


AMS-4 Remote Set Station permits manually adjustable set-point loading, or independent manual operation, of the control element.



AMBC-4 Cascade Biasing Station, used with pneumatic stacked diaphragm controllers, permits plus-or-minus biasing of a cascaded set-point to the controller.

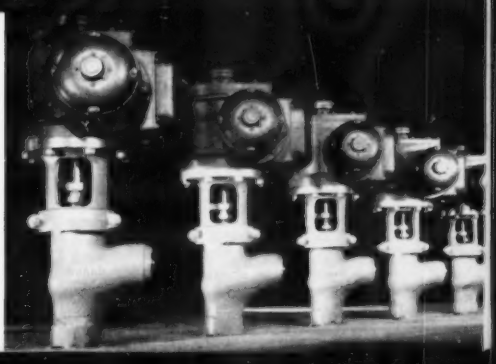
For details about Copes-Vulcan's complete line of pneumatic control stations, write for Bulletin 1031.



EDWARD CAST STEEL
GLOBE VALVE FIG. 4016Y

IMPACTOGEAR® OPERATED VALVE

MOTOR OPERATED VALVES



What's New from Edward Valves

New Products . . . Solutions to Problems . . . Information on Steel Valves from Edward, Long-Time Pioneer in the Field!

HOW TO SELECT CAST STEEL VALVES

Valves for today's high-pressure processes require economy, dependability and safety in operation. The material on these pages is designed to help acquaint you with a few basic principles and features you should consider when selecting cast steel valves 2½ inches and larger.

VALVE FEATURES FOR LONGER LIFE, EASIER OPERATION

Valve Handwheel should be large enough to operate valve easily. On smaller valve sizes, a knobbed handwheel design permits tighter grip. But for larger, high-pressure valves, impact-type handwheels will increase closing force, insure tighter closure (see large illustration opposite page). Quick closing can be obtained with impact-type handwheels geared for closing with the aid of portable air or electric wrenches (bottom-left, opposite page). Or, where central or automatic control is desired, consider fixed motor operation (bottom-right, opposite page).

Yoke Bushing on larger valves in higher pressure classes should be equipped with double ball-bearing construction for reduced operating torque and effective transmission of closing load (large illustration on opposite page shows this design). Material is important, too. On smaller valves, bushings of bronze will help prevent stem seizing or galling. Look for ample thread engagement between bushing and yoke and between bushing and stem.

Packing Chamber should be large enough to insure long packing life. Valve packing must allow the stem to move within the bonnet but must not allow any fluid leaks between them. Well made packing, formed specifically for the packing chamber and correctly compounded for your pressure-temperature service conditions, has much to do with satisfactory valve performance. Valves with a positive backseat for re-packing while under pressure offer additional operating advantages.

Bonnet Joint of bolted construction (see Fig. 618 this page) is easiest to work with on medium or small size valves. But for lasting bonnet joint tightness, in high-temperature services (and for reduced size and weight), pressure-seal bonnet joint design is best—no flanges or bolting to periodically restress (see large illustration opposite page). Not all pressure-seal designs are alike, however. Avoid gaskets with small sealing surfaces and sharp edges that can be easily damaged and large threaded gasket loading mechanisms that are hard to disassemble and give unknown gasket compression.

Disk Guiding that properly centers the disk into the seat for positive shut-off regardless of position is important. Valve bodies with integrally cast guide ribs supporting disk throughout travel are best. Avoid designs which attempt to guide by installing spider in seat opening.

Seat-Disk Joint—An integral hard-faced seat is generally regarded as superior to screwed seat construction because it eliminates body-seat leakage and retains hardness under temperature. A hard-faced disk or disk of special alloy is desirable in high temperature services; but 13 per cent chromium stainless steel is an excellent all purpose material below 750° F.

Body Design with streamlined flow passage areas (opposite page) reduces wear-producing turbulence, decreases pressure drop and delivers maximum flow. Valves with streamlined body contours will often permit the use of smaller pipe and valve sizes. Angle valves (see Fig. 7517Y, upper right) have even less pressure drop.

For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 360 Notre Dame Street, W., Montreal 1, Quebec.

Edward Valves builds a complete line of cast steel stop, check, non-return, stop-check and gate valves for pressures to 10,000 lbs. available with flanged or welding ends. Below are illustrated a few of the major valve designs from this complete line.

Fig. 7517Y
Angle stop valve, 1500 lb at 850 F. (3600 lb WOG), with integral Stellite seat, Stellited disk, pressure-seal bonnet, welding ends. 2½" to 14".

Fig. 618
Globe stop valve, 600 lb at 850 F. (1440 lb WOG), bolted bonnet, flanged ends, integral Stellite seat, Stellited disk. Sizes 2½" to 6".

Fig. 607Y
Angle non-return valve, 600 lb at 850 F. (1400 lb WOG), with pressure-seal bonnet, integral Stellite seat, Stellited disk-piston, welding ends, sizes 8" to 14".

Fig. 611—Gate valve, 600 lb at 850 F. (1440 lb WOG), with hard-surfaced seats and wedge, ball bearing yoke, flanged ends. Sizes 2½" to 12".

Fig. 4094Y—Horizontal check valve, 900 lb at 850 F. (2160 lb WOG), with integral Stellite seat, Stellited disk-piston, pressure-seal cover, welding ends. Sizes 2½" to 14".

Fig. 7514—Flite-Flow globe stop valve, 1500 lb at 850 F. (3600 lb WOG) or 2500 lb at 850 F. (6000 lb WOG), with extremely low pressure drop and other premium features. Sizes 10" to 18".

EDWARD STEEL VALVES
another fine product by
ROCKWELL

Catalog 14 contains full data on the complete Edward line of forged and cast steel valves from ¼" to 18"; in globe and angle stop, gate, non-return, check, blow-off, stop-check, relief, hydraulic, instrument, gage and special designs; for pressures up to 10,000 lbs: with pressure-seal, bolted, union or welded bonnets, with screwed, welding or flanged ends.

Background photo shows Cooper-Bessemer FM compressors for soot blowing service in a large western utility.

ECONOMICS OF BOILER CLEANING WITH COMPRESSED AIR (Versus Steam)

1. Pressure is always adequate to do clean, thorough job.
2. Better programming with air . . . gets better cleaning results for higher boiler efficiency.
3. Lower cost for blowing medium . . . less waste.
4. No quenching action on hot alloy tubes or pressure vessels.
5. Much less maintenance of blower equipment due to erosion, corrosion, packing wear.
6. Improved housekeeping . . . no steam or condensate leakage.
7. Greater over-all economy of blowing medium on evaluated basis.
8. Eliminates condensate makeup required when blowing with steam.

Soot blowing with air is faster, cleaner, less costly

...a report on soot-blowing applications by L. B. Schueler, *Power Plant Consulting Engineer, The Cooper-Bessemer Corporation*

The big reason why power companies and their consultants are switching from steam to air for soot blowing is *to reduce costs.* Compressed air does the job more thoroughly, uniformly, with less mess and at less cost. Its high efficiency increases the capacity, availability and economy of the entire furnace and boiler! Total maintenance cost is very much lower.

The whole story is given in the reprint of an article, "Steam or Air: Which costs more for boiler cleaning?" Write for your free copy. We will gladly work with you on your plans for compressor facilities for soot blowing . . . or other power plant needs. Call the nearest office.

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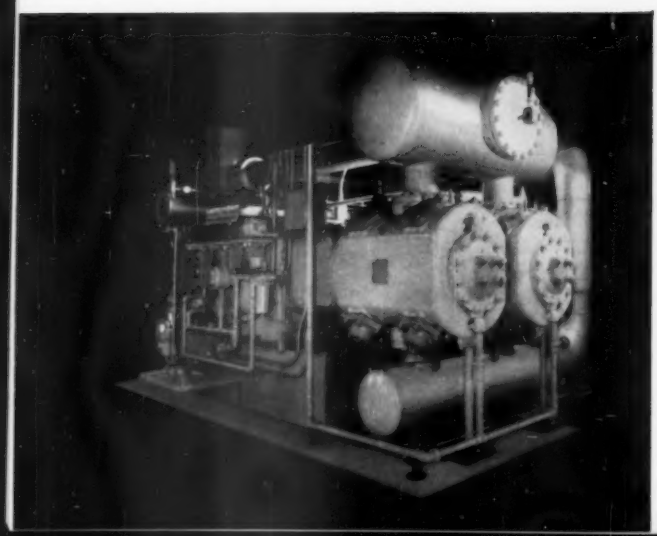
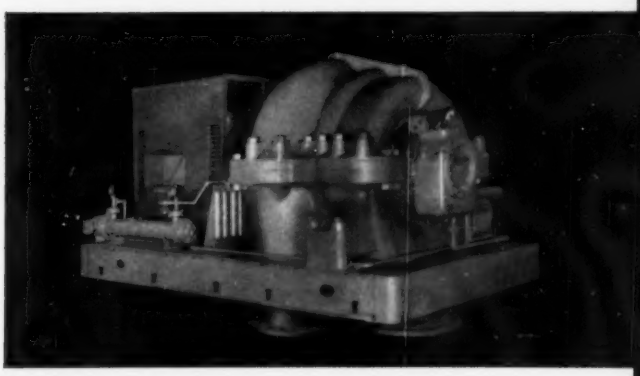
ENGINES: GAS - DIESEL - GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL
ENGINE, TURBINE OR MOTOR DRIVEN





Multi-stage centrifugal compressor. Available from 7000 cfm and up.

◀ *Multi-stage reciprocating compressor. Available up to 30,000 cfm free air.*

Compact and completely pre-assembled, Inland Empire Paper Company's Package Air Preheater is ready to be connected to a 100,000 lb/hr boiler. This particular Package Air Preheater (incidentally a repeat order), measures approximately 10'x10'x8', and its 7000 square feet of effective heating surface will recover about 360° F. from the stack gas. Package design cuts installation time and costs drastically.

Here's why
Inland Empire Paper Co.
chose a

PACKAGE AIR PREHEATER

BIG INSTALLATION SAVINGS — AND FUEL SAVINGS THAT CAN PAY FOR THE AIR PREHEATER WITHIN TWO YEARS.

Inland Empire Paper Company, Millwood, Wash., makes these big savings with their Package Air Preheater:

1. Low-cost installation. That single unit on the truck is a *complete* Package Air Preheater. Once in place, and the ducts and power line hooked up, it will be ready to go—installed without erection in a fraction of the time required for conventional units.

2. Short-term write-off. Records of Package Air Preheaters operating all over the country prove that Inland Empire's Package unit can pay for itself in two years, just on fuel savings alone!

You get this double advantage with the Package Air Preheater because it's completely shop-assembled. And its compact design brings all the advantages of continuous regenerative heat recovery to boilers as small as 25,000 lbs of steam per hr—or as large as 250,000 lbs per hr.

There are other important advantages, too. Get the whole story by writing today for your free 14-page booklet with all the facts and figures.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

New Nalco Coagulant makes Larger, Heavier Floc . . . Faster

Radically different Nalcolyte 110 used with Conventional Chemicals to Cut Costs, Speed Action in Water Clarification

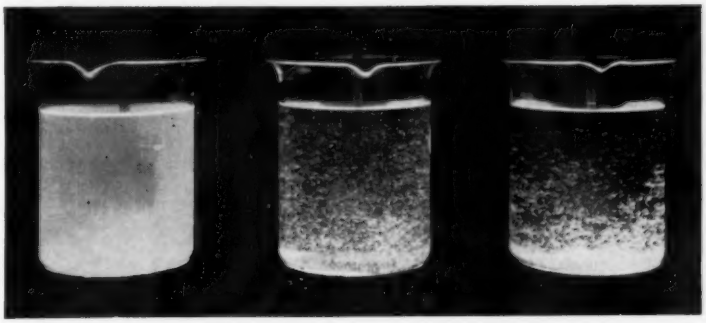


Photo taken in Nalco Laboratories 7 seconds after agitation stopped: *Left*, Control sample of untreated turbid water; *center*, same water, treated with 50 ppm alum; *right*, same water, treated with 20 ppm alum, 1 ppm Nalcolyte 110. Note that large, dense floc is settling out much more rapidly than center alum-treated sample.

Nalcolyte 110 is a new, non-ionic high polymer flocculant of very high molecular weight—over 1,000,000. It is used in extremely small dosages with conventional coagulants (such as sodium aluminate, alum, ferric sulfate) to increase size, density and uniformity of floc.

Less Chemical; Greater Capacity

Action of Nalcolyte 110 in creating heavier, larger, faster-settling floc not only permits greater throughput rates without floc carryover to processing equipment, but also cuts the total chemical requirements at a resultant cost saving.

In the example illustrated above, only 40% as much alum is required when Nalcolyte 110 is used.

May be Used in Potable Waters

Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 gives water works the opportunity to get appreciably greater capacity from existing clarification equipment—at lower treating cost.

High Suspended Solids No Problem

Waters containing high suspended solids respond quickly to Nalcolyte 110 coagulating action . . . frequently without other coagulant chemicals.

Typical high suspended solids waters which can be treated with speed and economy with Nalcolyte 110 are paper mill white water systems, industrial waste waters, mineral slurries and blast furnace gas wash water slurries.

Nalcolyte 110 Easy to Handle

Nalcolyte 110 is a coarse, white, free-flowing powder of non-toxic character. It is fed in dilute water solutions with standard liquid proportioning pumps or feeders. Stock solutions are prepared at concentrations up to 20%. Packaging is in convenient 25-lb. bags.

Data Available Promptly

Full information on Nalcolyte 110 for your coagulant use is ready to be sent upon your request. Write today, or call your Nalco Representative.

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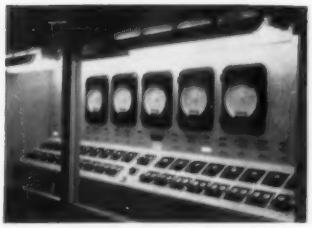
HAGAN NEWSLETTER
Behind the Panel



ANOTHER STEEL INDUSTRY FIRST FOR HAGAN

A large eastern mill has ordered what is believed to be the industry's first solid state combustion control system. Hagan PowrMag (magnetic amplifier) systems will be installed on a two-zone slab heating furnace, and will include zone temperature, zone fuel-air ratio, furnace pressure, recuperator temperature balance, and air pressure controls. Recording instruments (Hagan PowrLog) and panels will also be Hagan. Using PowrLog electronic recorders and PowrMag controllers, the system for each zone provides parallel operation of the combustion air damper and fuel oil control valve from the zone temperature controller. Fuel and air are measured and a fuel-air ratio correction is applied to the combustion air damper. The combustion air flow measurement is automatically compensated for temperature variations. Gas firing is contemplated for the future. (Item L-1)

GAS CONTRACT PENALTIES AVOIDED WITH RING BALANCE METERING

The increasing use of gas in the steel industry has brought about the necessity for central gas dispatching stations. By accurate control of gas usage, large users can avoid the penalties incurred when gas contracts are exceeded, and at the same time, make maximum use of available coke oven gas. Hagan Ring Balance meters have been chosen for this critical application by a large mid-western steel mill for a number of reasons, the most important being the inherent accuracy of the Ring Balance Principle. This basic accuracy is reinforced by the ability of the Ring Balance to compensate precisely for fluctuations in pressure and temperature, and the ease with which it can be calibrated. Add rugged construction, accurate electrical remote transmission and the ease with which range can be changed on a 7 to 1 basis, and the Ring Balance becomes the meter of choice for such applications. (Item L-2)

THESE SYSTEMS HAD TO BE EASY TO INSTALL

Easy to install—easy to calibrate—are commonly used phrases in the control business. But one Central American plant is willing to testify that this is strictly true—as far as Hagan systems are concerned. Combustion control, drum level control, meters and control panels were purchased from Hagan for a new 110,000 lb/hr boiler for a Central American steam electric station. Using Hagan instruction books and drawings, the entire system was installed, calibrated and put on the line without a single hitch, and a Hagan engineer has never been at the plant. All the systems have been functioning "beyond expectations" and maintenance has been minimum. (Item L-3)

HOW TO MEASURE A SMELL

To further decrease the risks of handling natural gas, an odorant is frequently added when the gas is transferred from underground storage areas back into the distribution system. The amount of odorant added is extremely critical, since too much makes the smell extremely objectionable, while too little makes the detection of gas leaks difficult. For this service, a pressure compensated Ring Balance meter, together with a Hagan ratio relay, controls a proportioning chemical feed pump. Installations of this accurate team are in service at a major gas supplier in the mid-west. Odorization of the gas is extremely accurate, and the installations have more than met the stringent specifications. (Item L-4)

HAGAN CONTROLS DO "SUBMARINE" SERVICE ON SURFACE VESSEL

One of our largest surface ships is equipped with Hagan controls, including combustion, feed water and boiler feed pump systems. On a recent cruise, a defective main condenser valve allowed a main machinery space containing the Hagan combustion and feed pump controls to be flooded. The control systems were under water for a total of 36 hours. Crew members cleaned up the equipment, and when the carrier docked, Hagan service representatives were requested to check out the control systems. The controls were found to be in first class condition, needing only two minor needle valve adjustments. Hagan marine systems are not only extremely accurate, providing the most economical operation, but they are built to "take it." (Item L-5)

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Hagan Building, Room 710, Pittsburgh 30, Pennsylvania
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If you would like more information on any of the above items, check the appropriate box below.

☐ Item L-1 ☐ Item L-2 ☐ Item L-3 ☐ Item L-4 ☐ Item L-5

QUALITY IS ALWAYS THERE IN VALLEY CAMP QUALITY COALS

From the time raw coal leaves the mine and is mechanically conveyed through all the processes of crushing, washing, sizing, and thermal drying, right up to shipment... quality, plus quality control, is a vital part of our coal preparation.

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In just 1 minute, an operator can check calibration of this L&N Magnetic O_2 Analyzer . . . can keep an easy watch on overall instrument accuracy, if desired. Under normal use, this check need only be made weekly. A complete calibration, requiring approximately ½-hour, only needs to be made every 3 months. Total calibration time: less than 3 hours a year.

The analyzer's regulating unit (shown above) is located right on the instrument. Calibration is simple since the measuring system is not disturbed. Instrument air serves as the calibrating gas.

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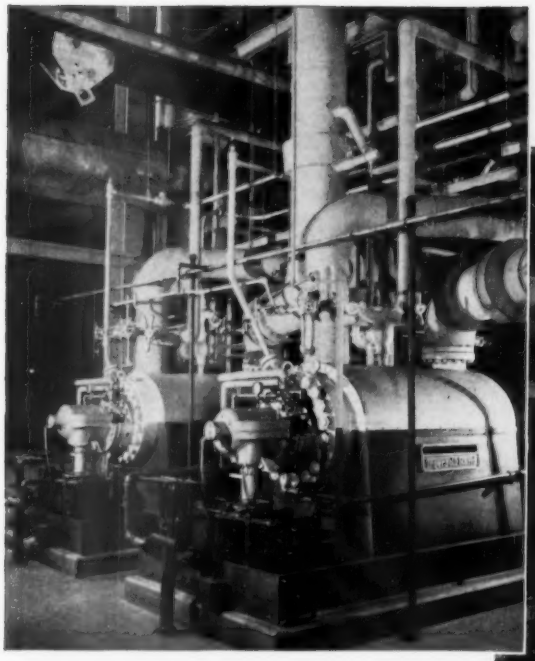
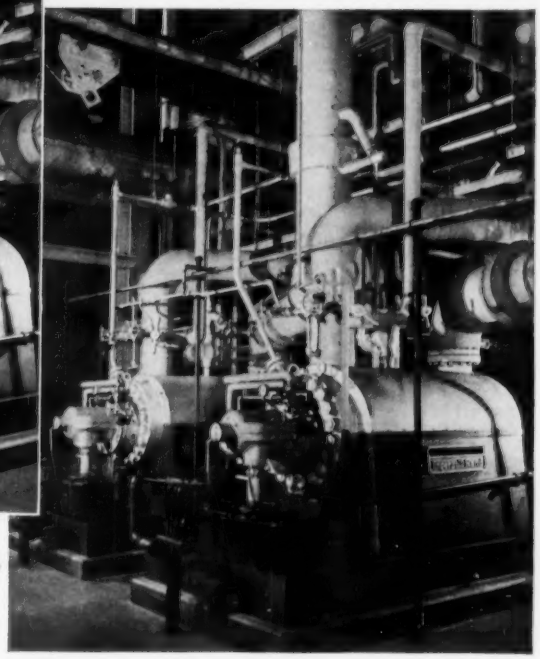


Two Ingersoll-Rand 11-stage CHTA boiler feed pumps now serving Unit No. 1 at Milliken Station.



Duplicate CHTA 11-stage boiler feed pumps are on order for Unit No. 2, now under construction.

2 MORE IR BOILER FEED PUMPS

for Unit No. 2 at MILLIKEN STATION

TO SERVE rapidly growing loads in the Finger Lakes area, New York State Electric & Gas Corporation is *doubling* the capacity of Milliken Station which went on line in Sept., 1955. Unit No. 2, now under construction, will be a duplicate of Unit No. 1 – consisting of a 135,000 kw turbo-generator with a capability of more than 150,000 kw.

The boiler feed pumps are also duplicates – two Ingersoll-Rand 11-stage CHTA units, each rated 1165 gpm at 5530 ft total head and driven at 3570 rpm by a 2000 hp motor. The I-R air compressors shown at the right for Unit No. 1 are also being duplicated for Unit No. 2.

Repeat orders like this are tangible *proof* of complete satisfaction with the units already in service. In leading power plants from coast to coast, I-R high-pressure boiler feed pumps with the exclusive unit-type rotor assembly are making impressive records of trouble-free performance – and resulting in repeat orders again and again.

For the best solution to your boiler feed pump problems, just get in touch with your nearest I-R representative.

Ingersoll-Rand

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Other I-R Equipment at Milliken Station

One of two Ingersoll-Rand Class TVH soot-blowing compressors serving Unit No. 1 at Milliken Station.

Two Ingersoll-Rand Class ES-NL compressors with non-lubricated cylinders, supplying oil-free instrument air for Unit No. 1. Another ES unit with standard oil-lubricated cylinder provides general plant air.

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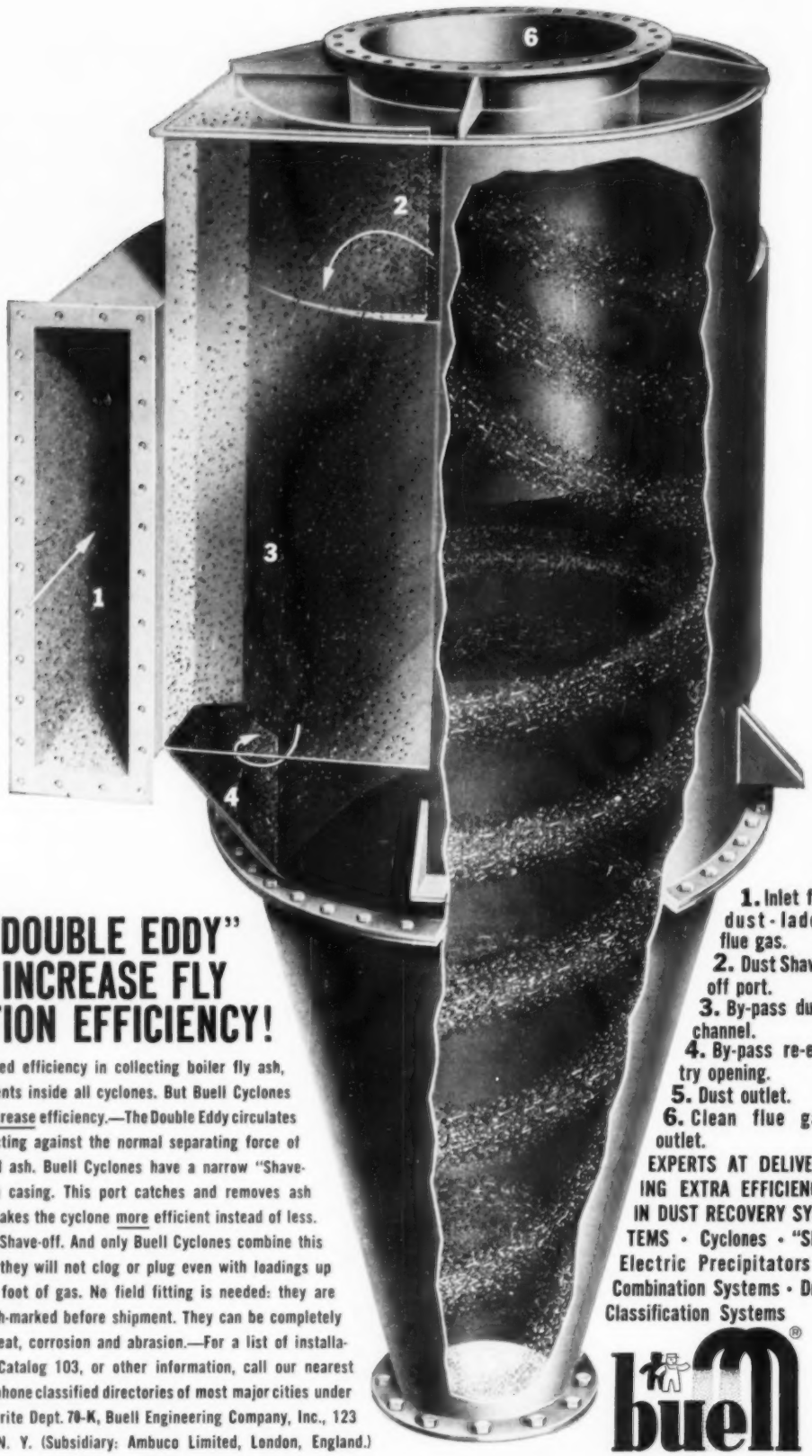

BUELL PUTS "DOUBLE EDDY" TO WORK TO INCREASE FLY ASH COLLECTION EFFICIENCY!

Ordinary cyclones provide limited efficiency in collecting boiler fly ash, because of "double eddy" currents inside all cyclones. But Buell Cyclones make the Double Eddy work to increase efficiency.—The Double Eddy circulates vertically inside all cyclones acting against the normal separating force of the spinning stream of gas and ash. Buell Cyclones have a narrow "Shave-off" port (2) at the top of the casing. This port catches and removes ash trapped in the Double Eddy. It makes the cyclone more efficient instead of less. —Only Buell Cyclones have the Shave-off. And only Buell Cyclones combine this efficiency with large diameter: they will not clog or plug even with loadings up to one pound of ash per cubic foot of gas. No field fitting is needed: they are completely assembled and match-marked before shipment. They can be completely lined, inside and out, against heat, corrosion and abrasion.—For a list of installations near you, a copy of our Catalog 103, or other information, call our nearest representative, listed in the telephone classified directories of most major cities under "Dust Collection Systems". Or write Dept. 70-K, Buell Engineering Company, Inc., 123 William Street, New York 38, N. Y. (Subsidiary: Ambuco Limited, London, England.)

1. Inlet for dust-laden flue gas.
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Editorial

The Fabulous Turbo-Encabulator

"The original machine had a base plate of prefabulated amulite, surmounted by a malleable logarithmic casing in such a way that the two spurving bearings were in a direct line with the pentametric fan." These words from the pen of some nameless humorist describe part of a mythical Turbo-Encabulator machine.

We were reminded of this bizarre device by an odd juxtaposition of effort at the recent ISA Conference and Exhibit in Chicago. Upstairs in a quiet hotel room devoted men were laboring to formulate and promote standards for instrumentation and control—to bring clarity of expression and improved understanding to a field which sorely needs them. But in the exhibit hall other men were striving with equal devotion to utterly confuse the poor wanderer who came seeking enlightenment. A valve, it appears, can not survive in the meteoric advance of control technology as a "valve"—it must be glamorized with a confusing title like "Hydro-Degenerator." Truthfully, we paused in front of a number of display booths for several minutes before we were able to determine the nature of the product being promoted. Confusion was rampant indeed and in such an atmosphere even a paraphrase of the famous Gertrude Stein line, "a valve is a valve is a valve" would have helped.

The time is now, we feel, for systems and component manufacturers and for technical writers on instrumentation and controls to forsake the trick words and the catch phrases—to forget the "turbo-encabulators." The talents of the men who generate these euphemisms could be put to far better use by service on some of the many committees of ISA working for standardization. No matter how dynamic or well endowed, a technology can not carry for long the wasteful burden of a completely confusing nomenclature.

Discussed and Disgust?

Our usually benign and placid nature has been ruffled of late by the performance of some who have been selected to discuss technical papers presented at various engineering society meetings. Selection as a discusser has always seemed to us to be a signal honor—implying as it does achievement and recognition of status in the engineering profession. Also implicit in designation as a discusser is the ability to logically analyze a paper and to comment lucidly on those points requiring further development, clarification or re-examination.

Unfortunately too many of those honored by being chosen to discuss a paper present their discussion in such a way as to indicate they had failed to read the paper under consideration. A definition of "discuss" supposedly obsolete except in medical terminology, reads "to dispel, to drive away." It is this obsolete definition that all too often appears to guide those whose discussions stray far from the subject or degenerate into thinly disguised papers of their own.

Neither shall they escape judgment who, in a "10-minute discussion," ramble on for an hour to the complete consternation of an already harassed chairman—not to mention the bewildered boredom of the audience. This latter type of discussion is not only inconsiderate but we have observed that where it occurs very little is contributed to the subject of the moment.

The heart of the issue is that presenting a discussion involves an obligation as well as an honor. This very real obligation demands a thorough reading of the paper and its reference material plus intelligent consideration of what has been said in light of the discusser's own research and experience on the subject. Finally it is mandatory that a discussion be written which, using the basic paper as a frame of reference, will contribute to the meeting by explaining, amplifying, arguing or indicating areas for further research. And finally common courtesy demands that the length of the discussion be confined to the standards of the meeting.

In these experiments a suspension of carbon black in fuel oil was added to various liquid fuels. It was found that flame emissivity at a fixed distance from the burner increased in approximate proportion to the increase in C:H ratio. In the case of fuel oil it is customary in industrial practice to inject the carbon as near to the burner as possible because of the difficulty in keeping more than 6 per cent carbon by weight in suspension for long periods.

Flame Emissivity and Radiation Effects From Adding Carbon Black to Liquid Fuels*

By E. H. HUBBARD, B.Sc.; M.Inst.GasE., M.Inst.F., A.I.M.†

Introduction

PREVIOUS work (1, 2)[1] has shown that one of the important parameters governing flame radiation is the carbon:hydrogen weight ratio of the fuel. These trials showed that fuel oil radiated more than gas oil and that pitch creosote radiated more than fuel oil.

A production trial carried out by the Shell Development Company and the Bethlehem Pacific Coast Steel Corporation showed that a 5 per cent carbon black addition to fuel oil resulted in a reduction of about 10 per cent in the fuel consumption per ton of steel made and a reduction also of about 10 per cent in the charge to tap time in an open-hearth furnace (3).

The questions which required answers were:

(*a*) Is there an increase in radiation when solid carbon is added to an oil flame?

(*b*) Can this increase in radiation be related to the C:H ratio of the mixture?

General Details of the Trials

These trials were carried out at the same time as those concerned with methods of fluid-atomizing oil flames (4), and the equipment used, and the general organization were the same as in those and previous trials (5).

Variables Studied

A 50/50 suspension of carbon black in fuel oil was added in turn to a gas oil and a fuel oil. The additions were made to give mixtures of various C:H mass ratios. The fuel rate for each comparison was then adjusted to give equal calorific inputs.

The mixtures were made by weighing into a 1-ton container which contained steam coils for heating and a circulation pump to prevent the suspension from settling. No difficulty was experienced when using gas oil as the basic fuel, but with fuel oil it was very difficult to prevent the carbon black from being deposited in all the flow lines and controllers. The maximum amount which could be added without mechanical difficulty was 10 per cent of the 50/50 suspension. Higher concentrations were tried but these caused considerable difficulty in the experimental installation.

In industrial practice the suspension is usually introduced as near to the burner as possible.

The input variables are given in Table I and the fuel analyses in Table II. A note on the carbon black suspension appears in the Appendix.

TABLE I—CARBON: HYDROGEN WEIGHT RATIOS OF MIXTURES USED

Fuel Without Carbon Additions		Addition of Carbon Black Mixture to Increase C:H Ratio		
Gas oil	6.47	6.97	7.45	7.66
Gas oil + fuel oil		6.96	7.53	7.83
Fuel oil			7.25	7.70

Calorific input, 1.1×10^4 kcal h^{-1}. Excess air, 20 per cent. Burner reaction thrust, 1800 g.

Results

For explanation of the figures see Ref. 4.

Comparison Between Gas Oil and Fuel Oil

The axial gas temperature in the fuel oil flame rose more rapidly than in the gas oil flame during the initial

* Reprinted from the Journal of the Institute of Fuel, July 1959.

† The British Petroleum Co., Ltd., Sunbury on Thames, Middlesex. Formerly Principal Investigator, International Flame Research Foundation.

[1] Numbers in parentheses refer to List of References at the close of the article.

TABLE 2—ANALYSIS OF FUEL

Flame	XI Fuel Oil	XIX Gas Oil	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	Carbon Black Suspension
C per cent	85.6	86.0	86.4	86.3	87.2	86.6	87.3	86.9	86.2	93.1
H_2 per cent	11.8	13.3	12.4	12.4	11.7	11.5	11.4	11.1	11.2	5.5
S per cent	1.2	0.7	0.6	1.0	0.7	0.9	0.7	0.9	1.2	0.5
H.C.V. cal/g	10,320	10,800	10,780	10,580	10,440	10,460	10,400	10,340	10,290	8,080
L.C.V. cal/g	9,680	10,090	10,110	9,910	9,810	9,840	9,780	9,740	9,690	8,780
Distillation, °C										
0 per cent	248	218	188	212	190	203	198	210	208	...
10 per cent	291	247	212	249	214	248	238	254	268	...
20 per cent	314	256	221	264	227	262	251	269	305	...
30 per cent	...	264	231	276	239	274	261	283	331	...
40 per cent	...	270	241	288	252	289	269	300	...	...
50 per cent	...	275	252	303	265	305	...	322	...	...
60 per cent	...	280	264	325	280	330	...	...	...	...
70 per cent	...	286	279	...	...	...	...	...	...	...
80 per cent	...	295	296	...	...	...	...	...	...	...
90 per cent	...	311	...	...	...	...	...	...	...	...
100 per cent	...	...	...	...	...	...	...	...	...	...
End point, °C	315	328	302	340	283	340	273	339	342	...
Percentage residue	0.79	6	16	34	38	36	54	45	65	...
C:H ratio	7.25	6.47	6.97	6.96	7.45	7.53	7.66	7.83	7.70	16.93

stages (see Fig. 1*a*). A possible reason for this is:

The heat of formation of the gas oil "molecule" is roughly three and a half times that of the fuel oil "molecule," so that on combustion more heat will be required to dissociate the gas oil, and hence the production of soot by thermal cracking will be slower. This is in agreement with common observation (compare with Fig. 1*b*). After cracking has taken place, the remaining gas has a higher calorific value per unit mass than before, so that the gaseous combustion, which occurs preferentially, will be concerned with a richer gas in the case of fuel oil than in the case of gas oil.

The fuel oil flame had a higher emissivity at the beginning because of the extra soot. A trace of soot persisted longer in the gas oil case, however, because the initial thermal cracking took longer.

The fuel oil used had a C:H ratio 12 per cent higher than the gas oil and gave a maximum flame radiation to a cold receiver about 35 per cent higher at the beginning of the flame falling to 10 to 15 per cent higher at the end.

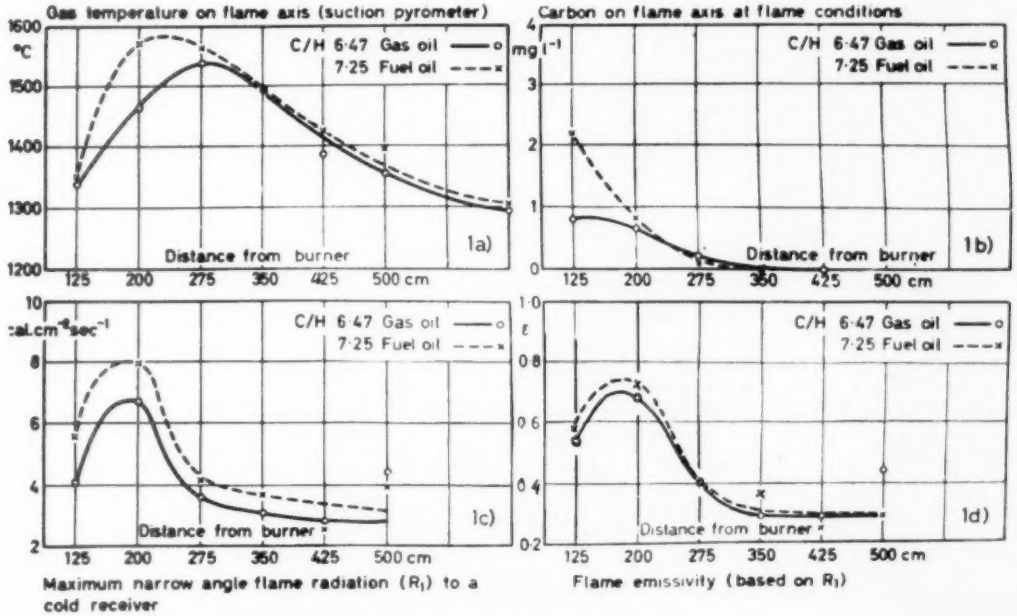

Fig. 1—Comparison between gas oil and fuel oil

1*a*—Gas temperature on flame axis (suction pyrometer). 1*b*—Carbon on flame axis at flame conditions. 1*c*—Maximum narrow angle flame radiation (R_1) to a cold receiver. 1*d*—Flame emissivity (based on R_1).

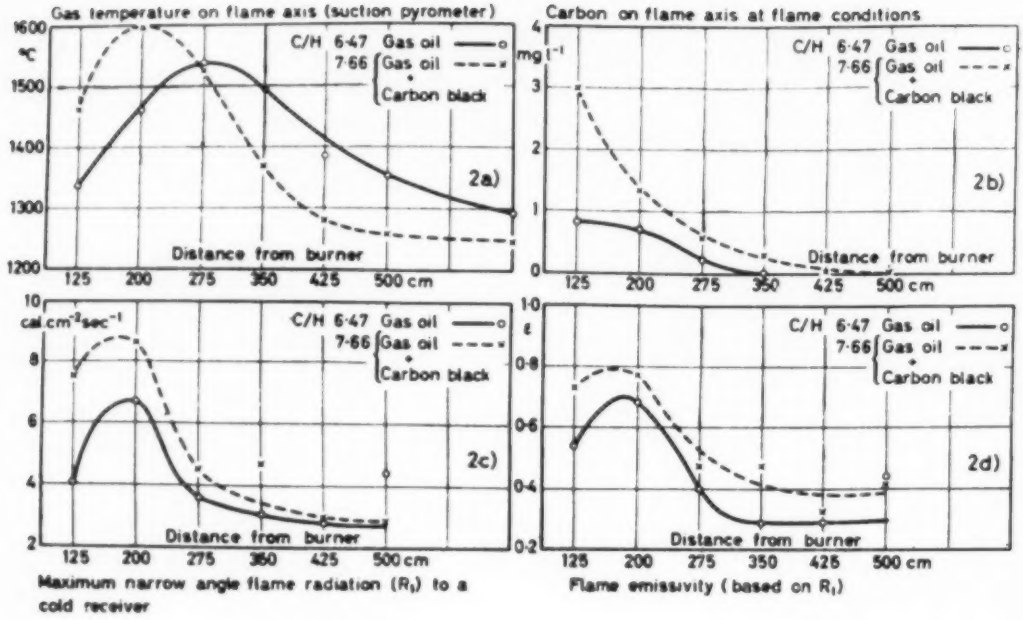

Fig. 2—Effect of addition of carbon black in fuel oil to gas oil

2a—Gas temperature on flame axis (suction pyrometer). *2b*—Carbon on flame axis at flame conditions. *2c*—Maximum narrow angle flame radiation (R_1) to a cold receiver. *2d*—Flame emissivity (based on R_1).

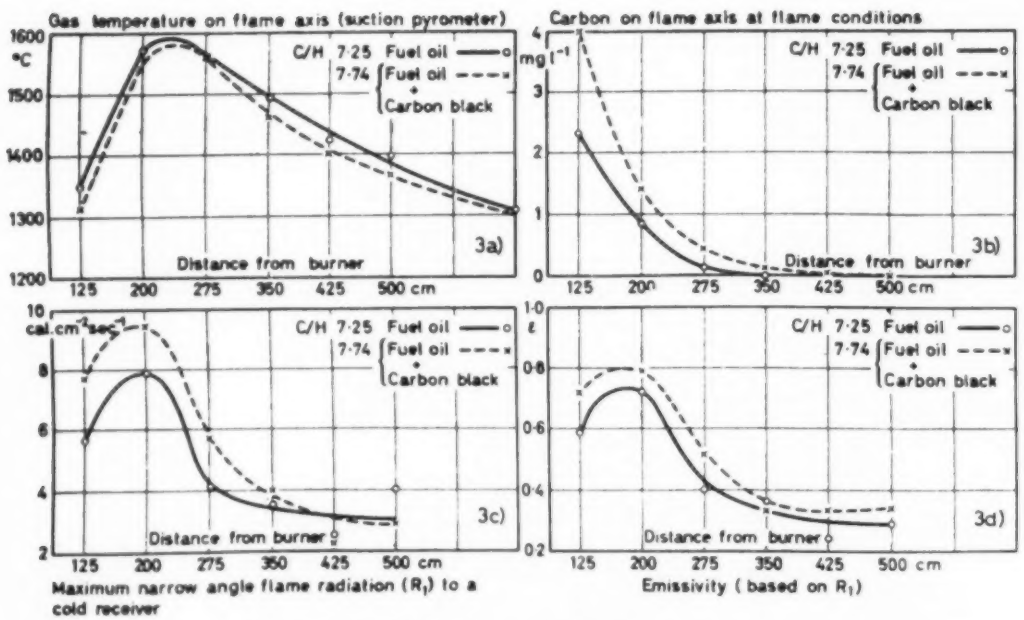

Fig. 3—Effect of addition of carbon black to fuel oil

3a—Gas temperature on flame axis (suction pyrometer). *3b*—Carbon on flame axis at flame conditions. *3c*—Maximum narrow angle flame radiation (R_1) to a cold receiver. *3d*—Flame emissivity (based on R_1).

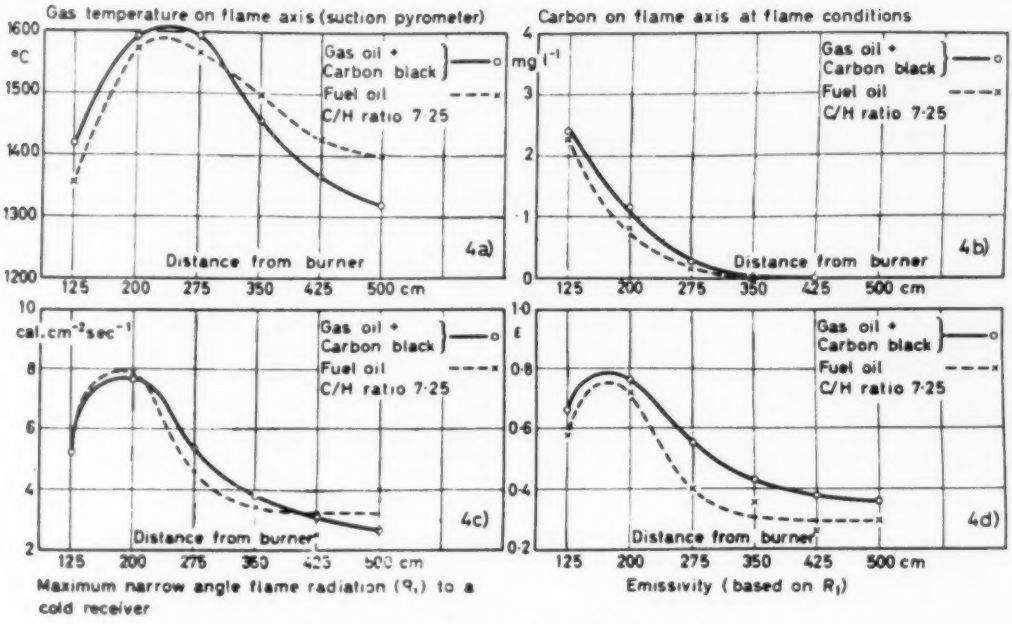

Fig. 4—Comparison between natural and added carbon

4a—Gas temperature on flame axis (suction pyrometer). *4b*—Carbon on flame axis at flame conditions. *4c*—Maximum narrow angle flame radiation (R_1) to a cold receiver. *4d*—Flame emissivity (based on R_1).

Effect of Carbon Black Additions

A 50/50 suspension of carbon black in fuel oil was added in turn to gas oil and fuel oil. More solid particles were found in the flame, as would be expected, and this was accompanied by a higher emissivity and radiation (see Figs. 2 and 3). Three levels of the suspension were added to the gas oil but only the data for the maximum addition (18 per cent by weight) are shown in the figures. The addition to the fuel oil was 8 per cent by weight.

It is interesting to note that the axial gas temperatures were only slightly affected in the case of the addition to fuel oil (Fig. *3a*) but that the same initial temperature differences appear in Fig. *2a* as in Fig. *1a*. This confirms that it was the fuel oil component in the suspension which caused the temperature difference.

At any given distance from the burner the increase in flame emissivity with additions of carbon to gas oil were roughly linear.

Comparison Between "Natural" and Added Carbon

Fig. 4 compares fuel oil with a gas oil which had the same C:H ratio by virtue of added carbon in suspension. The suspended carbon persisted slightly longer in the flame and raised the emissivity particularly at the tail of the flame. The flame radiation, however, was not much altered because of the lower end temperature.

At the beginning of the flame, where the axial gas temperature is lower than that in the outer burning sheath, the emissivity of the gas oil plus carbon black was higher than in the case of fuel oil, yet the flame radiation was the same. This can be explained if it is assumed that the temperature of the burning sheath in this case was higher with the fuel oil alone, possibly because the particles of soot were smaller than the added carbon.

Practical Applications

It is shown that additions of a carbon black suspension to both gas oil and fuel oil flames increase the flame emissivity, the increase being roughly proportional to the increase in C:H ratio (see Fig. 5). This implies that additions of solid carbon, or any higher C:H ratio fuel to a lower C:H ratio fuel will increase the emissivity. At the tail end of the flame the increase in emissivity for a given increase in C:H ratio due to added carbon black is larger than at the beginning of the flame because the added carbon persists longer than the natural soot.

Fig. 5 also shows that at constant C:H ratio there is little difference in flame emissivity near the burner between the various mixtures. At greater distances from the burner, also at constant C:H ratio, the fuel with the larger carbon black addition produces the higher emissivity.

It should be emphasized that a higher emissivity does not necessarily imply a higher overall radiant heat transfer. This is because if in one instance energy is liberated in a particular section of the flame the temperature will be relatively lower in subsequent sections. This is particularly true in situations such as the open-hearth furnace or the glass tank when the temperature of the receiving surface is sometimes very near to that of the flame itself. This could be avoided by arranging the fuel/air mixing to be at such a rate that a higher temperature could be

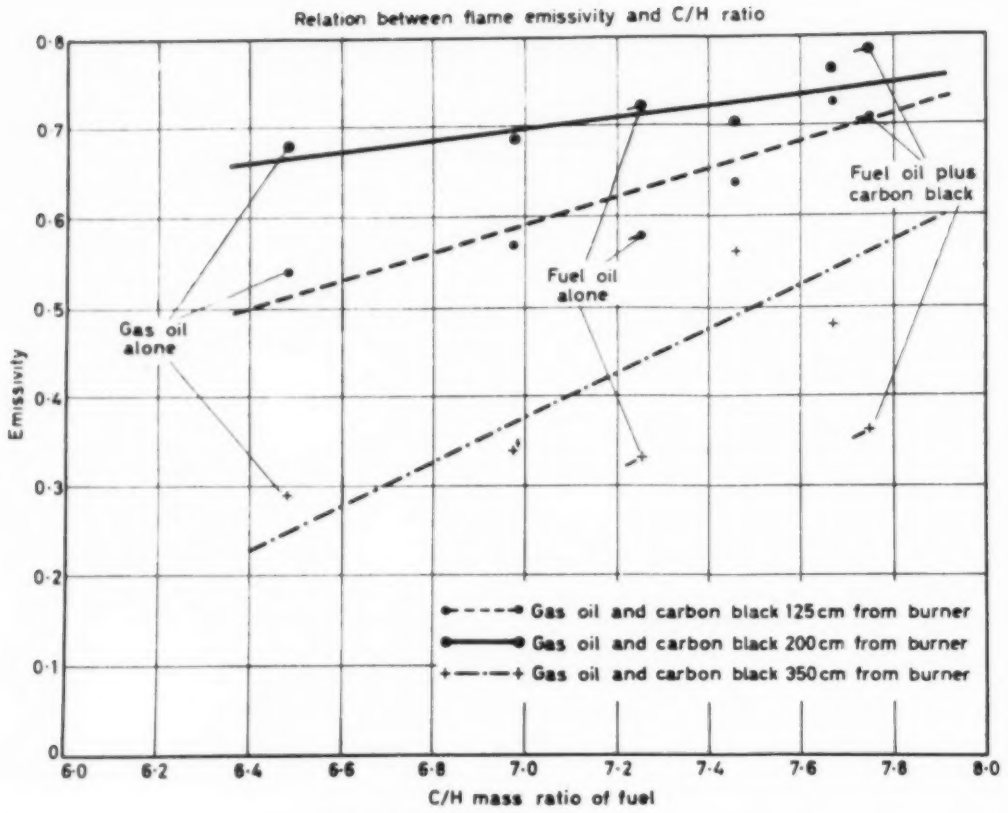
Relation between flame emissivity and C/H ratio
Emissivity
C/H mass ratio of fuel
Fuel oil plus carbon black
Fuel oil alone
Gas oil alone
Gas oil and carbon black 125 cm from burner
Gas oil and carbon black 200 cm from burner
Gas oil and carbon black 350 cm from burner

Fig. 5—Addition of carbon black to liquid fuels

maintained at the tail. One way of doing this would be to use a deficiency of combustion air at the beginning of the flame and to inject oxygen near its end.

It should be possible to use carbon of an optimum size which would be a balance between large diameters for slow burning and small diameters for increased emissivity.

Conclusions

The addition of solid carbon to liquid fuels increases the flame radiation because of the extra emissivity, and this is more evident at the tail end of the flame where the added carbon seems to persist longer than the natural soot. It should be possible to use carbon of a size which gives a balance between large diameters for slow burning and small diameters for increased emissivity. An important requirement, however, is that the carbon should be well maintained in suspension or preferably should be injected as close to the burner as possible to achieve maximum effectiveness.

The relation between flame emissivity and C:H ratio is shown in Fig. 5. It is seen that at the end of the flame the C:H ratio obtained by adding carbon is more effective in raising the emissivity than the natural soot formed by cracking.

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Appendix. Carbon Black in Fuel Oil

(Based on a private communication from Dr. H. Gershinowitz, Shell, New York.)

The carbon used was Shell Chemical Corporation's No. 53 carbon, which is produced by thermal cracking of methane at their ammonia plant in Pittsburg, California. It is separated by water quenching of the gases produced from the incomplete combustion of methane with air, subsequent filtering and drying. The carbon black so produced is strongly agglomerized and was milled to separate the particles. This was done in a ball mill. The oil was added at the same time so that the action of the ball mill not only deglomerized the carbon but also mixed it intimately with the oil. The size of this carbon black is about 0.5 micron although it is possible that some of the particles stick together so that the actual particles in the suspension may be larger than indicated.

The oil in the suspension was a light residual fuel oil. It has a carbon-hydrogen ratio of about 8.21 and a viscosity of about 27 to 30 SSF (about 7.5 deg Engler) at 50° C.

Waste heat boilers are finding an ever widening field of application in this country and abroad. The high dust loadings found in many industrial waste gases cause serious boiler cleaning problems. Here is the story of how Russian industry is currently meeting the problem of cleaning boilers with high dust loadings. In another article in the near future we will present some successful American methods of attacking this same problem.

By V. I. CHASTOUKHIN and E. L. ZARECHANSKY †

Vibration Cleaning Boiler Heating Surfaces*

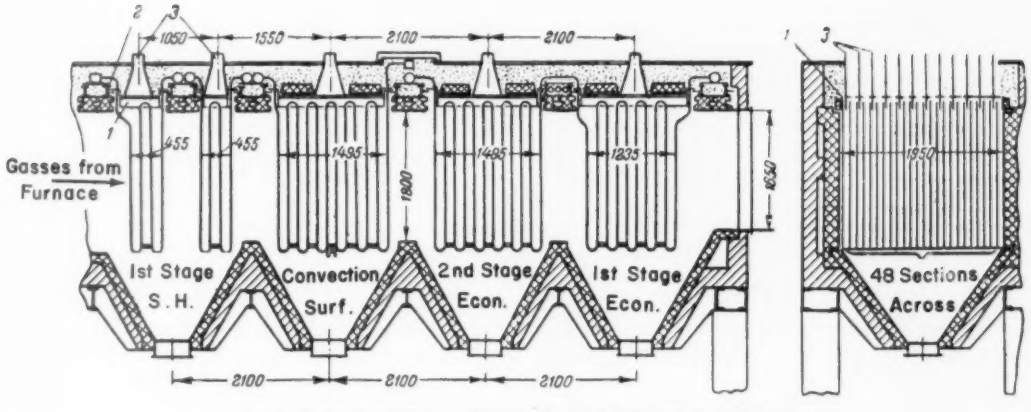

Fig. 1—Boiler convection section showing: (1)—T-beam for tube suspension, (2)—supporting beam for section suspension and (3)—trapezoidal support plates

FORKAUF (East German firm) LaMont type forced circulation boilers are used at some of the plants of the Russian liquor industry. These boilers burn a syrupy residual liquid from the distillation of alcoholic liquors which is a waste product of the industry. The heating surfaces of these boilers are made in the shape of pendent coils having $1^1/_4$" O.D. × 1" I.D. tubes (Fig. 1). The upper loops of the pendent surface are welded to the T-beams, shown as *1* in Fig. 1, and which rest on cross beams, *2*.

Some of the mineral salts of the alcoholic residual liquids deposit in the furnace chamber but for the most part they are carried with the furnace gases into the boiler gas inlets where they settle on the surface of the convection tube walls in the form of a white porous deposit. Since steamblast cleaning of the tube surface ash deposits turned out to be ineffective provision was made for periodical vibration of the spiral tubes. For this purpose trapezoidal plates, *3*, made from sheet steel having a thickness of 12 mm are welded to each of the beams (see Fig. 1) to which the pendent tubes are fastened.

Manual Rapping Unsuccessful

The plates, *3*, were manually rapped by a sledge hammer (3–4 blows at a time) in order to periodically clean the heating surfaces. This caused a vibration of the surface which was supposed to dislodge the ash deposits from the tube surfaces. However, this method proved unsatisfactory since the resulting vibration was weak and subsided quickly. Sledge hammer blows on the plates resulted in the formation of cracks in places where the

* Adapted from *Teploenergetika*, July 1959
† Candidates of the Technical Sciences, U.S.S.R.

surface was welded to the beams, *1*, and which proved to be a reason for frequent boiler shutdowns for repair. Also the manual rapping of the plates is extremely difficult and requires a great deal of labor. Subsequently, various mechanical vibrators were tested under operating conditions using different methods of connecting them to the boiler surface. The tests showed that the undirected action vibrators manufactured by Russian industry were not sufficiently effective. Good results were obtained by having directed action vibrators connected to the lower ends of the pendent sections.

Directed Action Vibrator

The directed action vigrator (Fig. 2) consists of two shafts, identified as *1* in Fig. 2, with eccentric weights placed in a cylindrical body, *2*. The shafts are connected with each other by a pair of gear wheels which rotate in opposite directions and forces are generated by the rotation of the two uneven masses. These act in opposite directions in the vertical plane and consequently reciprocally balance themselves out. In the horizontal plane they reinforce each other, thereby creating a directed vibration. The vibration method of cleaning was tested on the tube surfaces most susceptible to ash formation. The lower ends of the tubes were fastened with clamps to the component rod, shown as *1* in Fig. 3, one end of which penetrated through the boiler casing and which was fastened to the vibrator frame, *2*, by a flange coupling. The vibrator is suspended from the bracket, *4* in Fig. 3, on two hangers made from coil spring steel or from the link rods identified as *3*. A small electric motor is mounted under the vibrator and is connected with it by a V-belt drive. The motor must be in the same vertical plane with the vibrator shaft so that the vibration is not transmitted to the boiler frame. Vibrograms taken in various places on the casing and tube sections of the boiler showed that tube and vibrator oscillation is not transmitted to the frame or casing of the boiler with such an arrangement.

The tests were conducted at various frequencies caused by the tube vibration which is equal to the frequency of the vibrator oscillation. In order to exclude resonance, the frequency caused by the vibration was distinguished in all tests from the natural vibrations of the tube surfaces. Frequency change of the vibrator oscillation was obtained by varying the number of shaft revolutions. The best results in cleaning the tubes occurred with an oscillation frequency of 28–30 cps. The oscillation amplitude of various tubes at different sections varied from 0.3 to 1.5 mm. A satisfactory tube cleaning job is obtained by switching on the vibrator for 1.5–2 minutes every 15–20 minutes under the above operating conditions. The working load of the electric motor equaled 0.6–0.7 kw and the electric power consumption for cleaning the section amounts to approximately 2 kwhr for a 24 hour period.

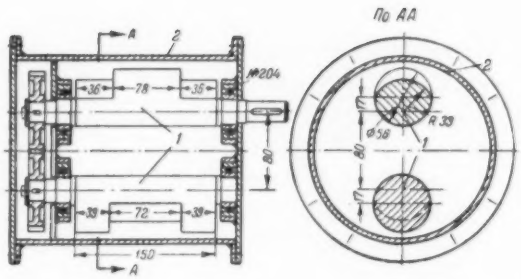

Fig. 2—A directed force vibrator showing: (1)—Vibrator shafts and (2)—vibrator frame

Mechanized vibration of the tube surfaces does not cause the formation of breaks and cracks in the welding areas (of the tubes to the beams). No leaks occurred in the section during either the period of the test of the mechanical cleaner or during the continuous observation period (3 months). At the same time in the other sections of the boiler where the pendent tubes were rapped manually, tube leaks and breaks in the welding areas (tubes to the beams) were frequent.

This vibration arrangement can be improved by replacing the stiff tube brackets (fastened to the beams) with free hangers on clamps.

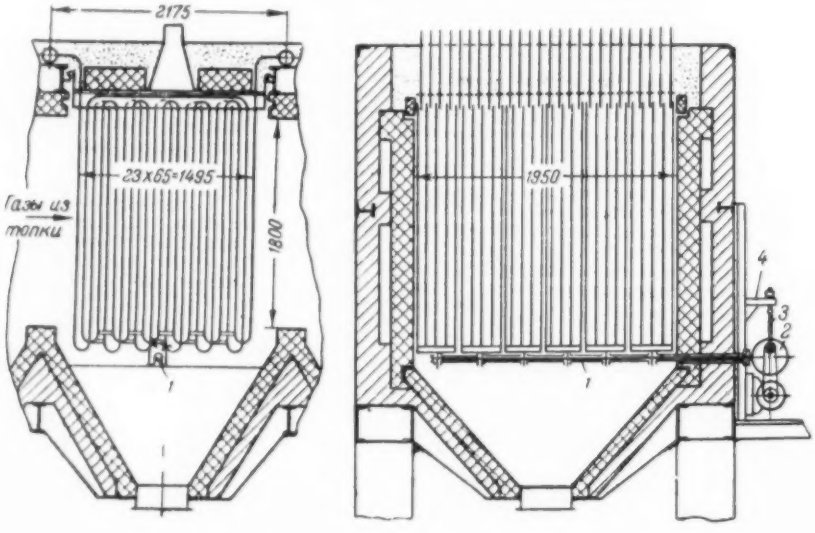

Fig. 3—Vibrator arrangement indicating: (1)—Tie rod, (2)—Vibrator, (3)—Coil spring steel hangers and (4)—Bracket for vibrator support

Information on coal ash behavior in the temperature range suitable for liquid ash removal and the effect of this property on boiler design and fuel characteristics is offered in this article. Further, a description of a method for predicting slag viscosity from ash analysis and fusion temperatures is given. Also a method is shown for predicting the flux requirements to obtain desired slag flow characteristics from an unsatisfactory fuel.

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Relationship of Coal Ash Viscosity to Chemical Composition*

WITH the growth of the slag tap boiler, the ability to predict accurately the fluid characteristics of the ash by laboratory means becomes increasingly important. In the past, because of the smaller units and the more abundant sources of coal, a miscalculation of coal suitability could usually be corrected by changing fuel sources. However, many modern plants because of location or long term contracts are often committed in advance to burn a specified coal.

Furthermore, the flow characteristics of an ash in relation to furnace temperature have considerable bearing on the design and selection of firing equipment.

Flow Characteristics

Ash fusion temperatures have long been used as a guide in predicting ash flow characteristics, but they have a shortcoming in that they do not tell how fluid the ash will be. Two coal ashes having the same ash fusion temperatures may have widely different flow characteristics, as illustrated on Fig. 1. The degree of fluidity is commonly expressed in terms of its viscosity or resistance to flow at a stated temperature.

Although the viscosity of a slag can be measured, this operation requires special high temperature equipment of a type not found in most coal laboratories. However, most commercial laboratories do have at their disposal means for determining the chemical composition of an ash. This can be done either by wet analysis or by more recently developed spectrographic means (1).[1] Hence an accurate means of predicting ash flow characteristics from chemical analysis provides a very useful tool in boiler design. It also provides information on how the flow characteristics of an ash may be altered by fluxing to obtain the desired characteristics.

Past Work

Ash as it exists in coal is composed chiefly of compounds of silicon, aluminum, iron, and calcium, with

* Presented at the joint meeting of AIME-ASME Solid Fuels Conference, Cincinnati, Ohio, Oct. 26 to 29, 1959, as Paper No. 59.

[1] Numbers in parentheses refer to similar numbered references at the end of the paper.

† Research Engineer. ‡ Group Leader of Fuels Section of Chemical Laboratory.

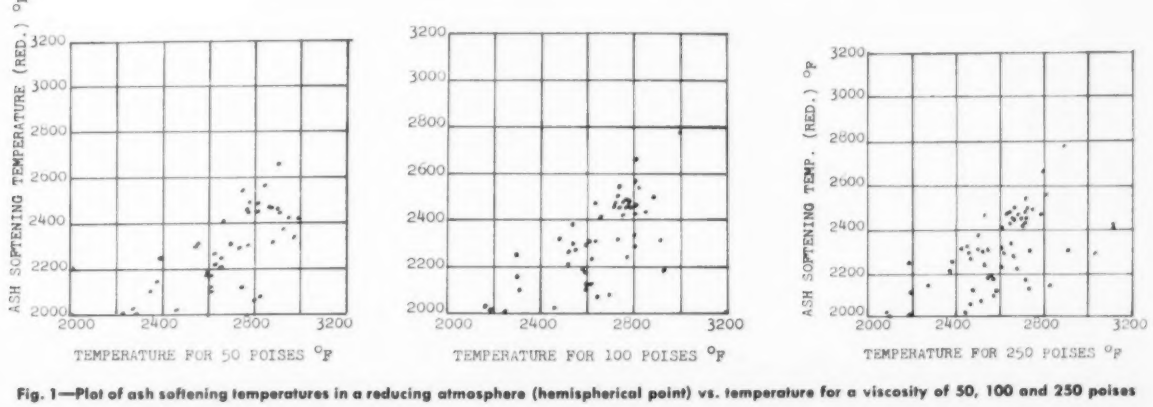


Fig. 1—Plot of ash softening temperatures in a reducing atmosphere (hemispherical point) vs. temperature for a viscosity of 50, 100 and 250 poises

smaller amounts of titanium, magnesium, sodium, potassium, and other trace elements.

Many attempts have been made in the boiler and in the steel industries to correlate the flow characteristics of slags with their chemical composition. Probably the most extensive investigation of the relationship of slag flow to chemical composition for coal ash slags that has been published to date was the one made by the Bureau of Mines (2–5). However, the scope of this investigation covered a limited range of ash composition.

Need for Additional Information

As new sources of coal for steam generation have come into use and as new and improved methods of firing and furnace designs have been developed the need for more detailed knowledge of ash characteristics has become increasingly important to operators and designers of slag tap boilers. To meet this need it has been necessary to expand and intensify our studies of ash behavior. These studies include ash characteristics that influence (1) fluidity in the tapping range, (2) boiler fouling, and (3) metal corrosion.

This paper discusses information on coal ash behavior in the temperature range suitable for liquid ash removal and shows how this is related to boiler design and fuel characteristics. A description of a method for predicting slag viscosity from ash analysis and ash fusion temperatures is shown.

The scope of this investigation has included a review of available information from previous data and from pub-

TABLE I—DATA ON COALS USED FOR VISCOSITY DETERMINATIONS

Code No.	Chemical Analysis, %								Ash Fusion Temperature, °F			Measured slag Viscosity, Temperature °F for Poises			Ferric, %	Base to Acid Ratio	Equivalent SiO_2, %	Silica to Alumina Ratio	T_{cv}
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	ID	ST	FT	50	100	250					
									Coals										
1	31.0	20.0	28.0	1.4	10.0	1.7	7.8	2.6	1970	2030	2380	2270	2160	2080	24.6	0.95	43.9	1.55	2180
1a												2555	2530	2485	82–90				2570
2	34.0	21.0	29.0	1.1	9.8	2.1	4.6	1.1	19.80	21.80	24.20	2600	2580	2540	80–85	0.84	45.4	1.62	2620
3	34.0	18.0	26.5	1.1	5.1	1.0	7.0	3.0	1940	2190	2440	2600	2580	2550	72–87	0.80	51.0	1.89	2610
4	34.2	18.6	41.2	0.8	1.0	0.9	0.3	1.8	1940	2110	2440	2340	2305	2190	7–17	0.84	43.2	1.84	2420
4a												2600	2590	2580	70.0				2600
5	34.4	20.1	40.4	0.6	2.0	1.0	0.3	1.2	1940	1980	2390	2285	2240	2190	13.0	0.81	44.3	1.72	2380
6	36.0	19.0	29.0	1.0	7.2	1.4	5.0	1.8	1960	2180	2480	2610	2590	2570	63–83	0.80	48.9	1.90	2630
7	36.8	36.7	17.4	1.2	4.5	1.6	0.9	0.2	2270	2310	2770	2690	2600	2490	13.0	0.34	66.1	1.00	2660
8	37.7	29.9	15.7	1.0	8.1	5.6	0.7	1.1	2240	2320	2590	2550	2470	2425	29.6	0.455	56.2	1.24	2480
9	38.1	37.1	14.2	0.5	4.3	0.9	1.3	1.6	2360	2460	2820	2770	2730	2665	25.0	0.29	66.2	1.03	2780
10	38.3	22.4	5.3	1.7	24.9	5.9	0.5	0.2	2120	2160	2410	2380	2290	2270	37.0	0.59	51.5	1.72	2280
10a												2390	2320	2300	64.0				2320
11	39.0	18.5	27.0	1.1	5.6	0.7	3.9	3.2	1910	2100	2500	2610	2590	2570	68–78	0.69	53.1	2.11	2610
12	39.0	22.5	35.7	0.9	1.4	0.8	0.3	1.9	1960	2120	2430	2610	2590	2580	60.0	0.64	50.6	1.73	2625
13	39.4	28.8	28.0	1.2	1.1	0.5	0.0	0.4	2050	2300	2500	2540	2530	2510	30.0	0.44	55.0	1.37	2565
14	40.0	18.0	35.0	0.1	4.3	1.2	0.3	2.2	1960	2030	2420	2455	2450	2445	63.0	0.73	49.7	2.22	2480
15	40.2	31.3	10.4	0.8	13.6	2.4	0.5	0.8	2320	2380	2670	2590	2530	2495	26.0	0.38	60.4	1.28	2540
16	41.0	21.0	29.0	1.1	5.9	0.7	3.4	2.0	1970	2230	2560	2630	2620	2600	73–80	0.65	53.5	1.95	2630
17	41.4	32.4	3.7	1.9	9.6	4.8	2.3	2.2	2060	2130	2670	2740	2610	2470	23.5	0.30	69.8	1.28	..
18	42.0	33.8	15.6	1.4	1.4	1.3	2.8	0.4	2240	2500	2790	2780	2720	2660	30.0	0.28	69.7	1.24	2720
19	42.0	14.5	31.0	0.6	5.3	1.9	0.7	2.0	1980	2010	2280	2230	2180	2090	10.0	0.72	52.5	2.90	..
20	42.1	29.8	18.0	1.6	2.6	1.9	1.4	2.5	2150	2270	2740	2630	2540	2455	23.0	0.36	64.1	1.41	2560
21	42.6	26.8	11.8	1.3	11.5	3.1	0.6	2.2	2260	2330	2730	..	..	2445	30.0	0.41	60.9	1.59	2450
22	42.8	24.5	27.8	0.9	1.8	0.5	0.2	0.2	1970	2410	2490	2665	2650	2610	57.0	0.46	58.7	1.75	2690
23	43.6	35.9	8.8	1.2	7.5	1.5	0.1	1.0	2440	2550	2800	2740	2730	2710	20.0	0.23	71.1	1.22	2740
24	44.1	26.9	13.5	1.4	10.1	2.7	0.8	0.5	2200	2290	2620	2730	2590	2450	29.0	0.38	62.7	1.64	2440
25	45.2	30.3	14.5	0.9	2.5	2.0	1.0	3.6	2150	2310	2770	2770	2625	2535	25.0	0.31	70.5	1.49	2540
26	45.3	31.3	13.4	0.7	3.9	1.2	0.6	3.5	2320	2490	2840	2810	2760	2750	20.0	0.29	71.0	1.44	2760
26a												2840	2780	2770	29.0				2780
27	45.3	30.3	19.0	0.7	2.1	0.2	0.1	1.4	2120	2460	2820	2760	2700	2690	32.6	0.29	68.0	1.48	2700
28	46.3	32.6	12.5	1.4	2.7	1.5	0.3	2.7	2200	2420	2880	2900	2810	2785	21.0	0.25	73.5	1.42	2825
29	46.8	30.3	15.2	0.9	3.1	0.9	0.6	0.2	2410	2570	2740	2840	2810	2810	43.0	0.25	71.0	1.54	2820
30	47.5	31.8	15.3	1.5	0.5	0.8	0.2	2.1	2220	2660	2850	2900	2810	2795	18–31	0.23	74.1	1.49	2840
31	47.9	29.3	11.0	1.2	2.8	2.2	0.8	4.6	2150	2280	2850	2930	2800	2650	20.8	0.27	75.1	1.64	2640
32	48.1	31.0	11.2	1.0	2.0	1.7	0.3	4.7	2190	2420	2830	..	2740	2690	20.0	0.25	75.3	1.55	2740
33	48.3	28.0	11.5	1.7	1.8	4.0	0.8	3.9	2200	2320	2800	2880	2720	2610	21.4	0.28	73.7	1.73	2620
34	48.5	27.6	15.3	1.3	0.7	2.1	4.0	0.6	2270	2460	2740	2910	2760	2660	28.0	0.29	72.9	1.76	2660
34a												2910	2760	2700	38.0				2715
35	48.6	30.0	8.6	2.4	3.6	2.1	0.4	4.0	2300	2490	2810	..	..	2740	20.0	0.23	77.3	1.62	2745
36	49.2	27.2	16.8	1.4	0.8	3.4	0.6	0.2	2120	2460	2760	2810	2780	2710	43.0	0.28	70.1	1.81	2785
37	49.5	30.0	6.9	2.5	6.7	3.0	0.2	0.5	2230	2470	2830	2900	2760	2630	17.0	0.21	74.9	1.65	2670
38	49.5	25.8	9.7	1.1	4.7	2.3	4.4	1.3	2150	2290	2750	..	2800	2620	30.3	0.29	74.8	1.92	..
39	49.6	24.4	10.3	1.2	5.8	2.4	3.8	1.7	2090	2340	2750	2970	2800	2640	26.7	0.32	72.9	2.03	..
40	50.2	27.6	14.3	1.2	2.9	0.7	0.4	2.5	2380	2500	2830	..	2880	2720	25.0	0.26	73.7	1.82	2730
41	50.2	27.1	12.2	1.4	2.7	1.7	0.3	3.9	2130	2480	2860	..	2745	2635	18.0	0.26	75.3	1.85	2645
42	50.7	25.8	18.8	1.3	0.4	0.8	0.2	1.8	2130	2470	2760	2870	2710	2670	23.0	0.28	71.9	1.96	2670
43	51.3	30.6	5.4	1.0	5.4	2.7	1.1	1.9	2250	2430	2830	2990	2850	2705	23.5	0.20	79.2	1.68	2550
44	51.4	22.1	19.1	1.7	1.7	1.4	0.2	2.3	2080	2240	2770	..	2770	2530	19.0	0.33	69.6	2.30	2535
45	52.3	27.2	10.6	1.5	2.7	1.5	0.4	3.2	2390	2550	2860	..	2820	2700	20.0	0.22	78.0	1.92	2680
46	52.9	27.0	5.8	1.8	6.1	2.3	0.3	3.2	2340	2480	2850	2860	2780	2710	27.0	0.25	78.7	1.96	2600
47	52.9	25.1	8.6	1.1	3.7	2.0	0.5	6.0	2160	2310	2900	..	2910	2730	23.0	0.21	78.7	2.10	2490
48	52.9	25.6	15.2	0.8	2.6	1.1	0.5	1.0	2140	2430	2750	2940	2800	2640	24.4	0.26	73.6	2.06	2640
49	53.0	17.0	17.0	0.7	4.0	1.0	0.5	3.1	1920	2080	2480	2830	2680	2510	58.0	0.35	70.7	3.12	2425
50	61.0	20.2	7.1	0.9	6.4	1.2	1.3	1.9	2120	2310	2870	..	..	2900	42.0	0.21	80.7	3.02	2810
51	63.6	19.1	3.3	0.8	5.8	1.0	3.5	2.8	2120	2290	2860	..	..	3030	Air	0.20	86.4	3.33	..
52	66.0	19.2	3.1	0.7	6.0	1.5	1.1	2.4	2240	2430	2850	..	..	3100+	41–50	0.164	86.2	3.44	..
53	66.8	19.8	2.4	0.6	6.1	1.3	0.9	2.1	2270	2400	2870	..	..	3100+	48–55	0.15	87.2	3.38	2880
54	69.5	17.8	2.4	0.9	5.3	0.9	1.2	1.9	2230	2420	2890	..	..	3100+	Air	0.13	89.1	3.90	..
									Coals + Additives										
1b	41.0	18.0	25.0	1.0	6.0	2.0	7.0	2.0	..	..	..	2530	2490	2450	78–85	0.70	55.5	2.28	2545
1c	57.0	13.5	18.0	1.0	5.0	1.3	4.5	3.0	..	..	..	2780	2600	2430	66–71	0.45	70.1	4.22	2390
11a	37.0	16.0	22.0	1.0	3.2	1.1	15.0	1.6	..	..	..	2370	2240	2130	86–92	0.89	58.4	2.31	2190
11b	38.0	17.0	24.0	1.1	3.8	1.3	12.0	2.4	..	..	..	2540	2510	2460	72–88	0.78	56.6	2.24	2540
11c	39.0	14.0	21.0	0.9	18.0	1.1	3.4	2.4	..	..	..	2290	2260	2240	79–91	0.85	49.4	2.78	2320
11d	44.0	16.0	21.0	1.0	11.0	1.1	3.7	1.6	..	..	..	2450	2430	2400	76–88	0.63	57.1	2.75	2460
11e	45.0	19.0	25.0	1.0	3.1	1.2	4.5	3.2	..	..	..	2420	2290	2210	13.3	0.56	60.6	2.37	2290
11f									..	..	..	2585	2565	2540	70–80				2610
52a	57.5	30.6	2.6	0.8	4.6	1.3	0.7	1.9	2320	2780	2900+	..	2990	2880	48–55	0.13	87.2	1.88	2880
53a	45.7	13.6	1.6	0.4	35.8	0.8	0.6	1.5	2210	2250	2440	2400	2290	2185	39.0	0.68	54.5	3.36	..
53b	46.6	26.5	2.4	0.5	20.7	1.3	0.6	1.4	2400	2470	2720	2760	2630	2525	50.0	0.36	64.4	1.76	2530
53a	52.3	15.4	23.6	0.5	4.5	1.1	0.6	1.7	1940	2070	2710	2800	2640	2460	25.0	0.46	64.0	3.40	..
53d	52.7	15.5	1.9	0.5	26.0	1.1	0.6	1.7	2180	2210	2420	2650	2510	2370	25.0	0.45	64.6	3.40	..
53e	52.7	15.6	1.9	0.5	17.1	9.9	0.6	1.7	2230	2260	2680	2650	2510	2380	37.5	0.45	64.6	3.38	..
53f	58.7	17.3	8.3	0.5	11.4	1.2	0.7	1.9	2040	2140	2900+	..	..	2730	18.0	0.31	84.4	3.39	..
53g	59.5	17.6	13.2	0.5	5.4	1.2	0.7	1.9	2060	2160	2900+	..	..	2830	28.0	0.29	85.9	3.38	..
53h	59.8	17.7	2.1	0.5	16.1	1.2	0.7	1.9	2040	2180	2800	..	2920	2710	28.0	0.29	75.5	3.38	..
53i	59.8	17.7	2.1	0.5	11.6	5.7	0.7	1.9	2170	2230	2820	..	..	2670	25.0	0.29	75.5	3.38	..

lished articles along with a coordinated two-phase test program:

1. Test firing a number of fuels to observe slag tapping characteristics in laboratory and commercial units.
2. Determining slag viscosity and chemical analysis of these and many other ashes. This work included ashes altered by the addition of chemicals. Data on these slags are tabulated in Table I. A description of the viscometer used is included in the Appendix.

The results of these studies provide a practical basis for delineating the relationship that exists between (1) slag viscosity and furnace temperature, and (2) chemical analysis and the viscosity of a slag.

The influence of these relationships in predicting the slag tapping limitations of a power boiler will be discussed in the following.

I. Relationship between Slag Viscosity and Furnace Temperature

In order to predict the suitability of a coal ash for liquid slag removal, it is necessary to know its flow characteristics in relation to temperature. Fluidity of a slag is usually described by giving its viscosity in poises at a stated temperature. In order to establish these limits, tests were made on a number of units where the temperature of the slag was obtained by optical pyrometer, and its viscosity was determined by laboratory tests of a slag sample. Results of these tests show that the slag viscosity as it taps from a boiler may vary considerably; however, it is normally within the range of 50 to 100 poises with 250 poises as an upper limit. Data reported by the Bureau of Mines serve to confirm these findings (3). There are no commonly used liquids having viscosities in these ranges; however, to give some visual concept the viscosity of

Water at 68 F	=	0.01 poise
SAE #10 oil at 68 F	=	1.00 poise
Glycerine at		
68 F	=	15.00 poises
32 F	=	120.00 poises
0 F	=	1300.00 poises

The boiler designer has some control over setting the limits for satisfactory slag tapping from a furnace in the arrangement of the water-cooled surface and in directing the flow of the furnace gases. However for a given furnace design and slag composition, the governing factor in determining whether the slag will tap satisfactorily from the furnace is the furnace temperature. Furnace temperature at the tapping zone is the adiabatic or theoretical[2] furnace temperature minus heat losses up to this point. Once the fuel analysis, excess air, and air preheat are known, the theoretical furnace temperature can be calculated. Calculating heat loss to the enclosure is quite involved; however, for predicting limits on slag tapping ability it can be compensated for by knowing the relationship between furnace surface and total heat release. These relationships are plotted on Fig. 2 for a typical boiler design to show the upper limits on satisfactory liquid slag tapping. For example, this figure shows that this unit, for a theoretical furnace temperature of 3900 F, a slag having a viscosity of 250 poises at 2600 F would tap satisfactorily at rated capacity. However, if the rating were dropped appreciably slag flow would cease. This does not mean that such a boiler cannot operate at 50 per cent rating, but only that it would not tap liquid ash until rating is increased. Further study of this figure shows that ash viscosity limitations are lower on a small unit of given configuration because of the higher surface to heat release ratio.

To calculate the theoretical furnace temperature it is necessary to know three things: (1) the fuel analysis, (2) the amount of excess air, and (3) the degree of air preheat. For example, at 600 F air preheat and 10 per cent excess air, the normal range is from 4100 F for a high rank eastern coal of low ash and moisture content down to 3500 F for a midwestern coal of 20 per cent moisture and 20 per cent ash. Furthermore, once the tapping limitations for a unit have been established on one coal, Fig. 2 can also be used to predict limits on other fuels by

[2] Theoretical furnace temperature as used here is the calculated temperature obtainable neglecting dissociation but allowing for the heat loss to the moisture and to the slag.

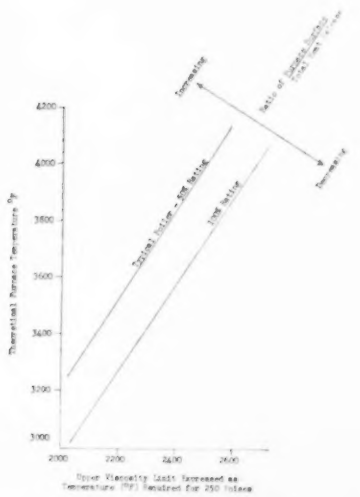


Fig. 2—Relation of theoretical gas temperature to temperature of slag required for a viscosity of 250 poises

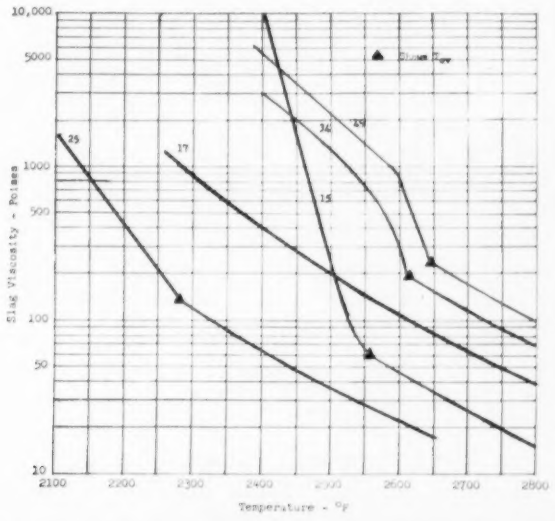
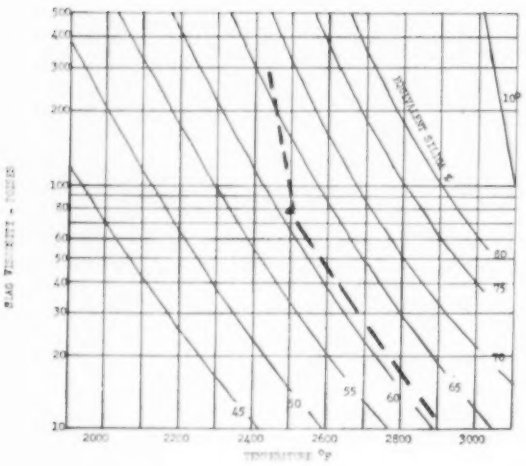


Fig. 3—Viscosity-temperature plots of typical slags—Refer to Table I for analyses as listed by number



Sample Ash Analysis, %

SiO_2	45.0
Al_2O_3	20.0
Fe_2O_3	15.0
TiO_2	2.0
CaO	10.0
MgO	3.0
Na_2O	2.5
K_2O	2.5
AST (Red.)	2300 F

Calculations

$$\text{Equal. Silica} = \frac{45}{45 + 15 + 10 + 3} = 61.6$$

$$T_{cv} = 2300 + 200 = 2500\ F$$

Fig. 4—Plot of viscosity vs. temperature for various equivalent silica percentages

locating the limiting point for temperature and viscosity and drawing a curve parallel to those shown on this figure.

II. Relationship of Ash Viscosity to Chemical Composition

The chemisty of coal ash is quite complex due to the number of elements involved and the reactions that take place. Several simplified methods of predicting slag behavior based on chemical analysis of the ash have been proposed.

The two methods described below are not original with the authors but are modifications of previously proposed methods with additional data to support their validity. The first of these is a modification to the method proposed by the Bureau of Mines (4), which permits plotting a reasonable approximation of the viscosity-temperature relationship in the tapping range.

The second method shown relates ash viscosity to the base-to-acid ratio of the chemical constituents. This method is more applicable to predicting the effect of flux additions or the result of blending two or more fuels.

Modified Bureau of Mines Method

Measured viscosities of a large number of coal ashes show that, as a slag is cooled from the true liquid state, its viscosity increases along a logarithmic curve until some point is reached where it deviates and viscosity tends to increase more rapidly as temperature is decreased. The point at which this deviation takes place has been termed "the temperature of critical viscosity," T_{cv}, and its occurrence will be discussed later. The deviation may be gradual or it may take place rather sharply (Fig. 3), and is described as the point at which solid material begins separating from the liquid, resulting in a mixture of both. Measurements beyond this point are no longer true viscosities; however, they do give an apparent viscosity which can be used as a measure of flow characteristics. Through proper correlation of these data, the measured viscosity values of a slag can be related to its chemical composition and to the degree of oxidization of the iron in the slag.

Viscosity in the Liquid Range. There are many ways by which the relationship of viscosity in the liquid range to chemical analysis may be correlated. However, the method proposed by the Bureau of Mines is comparatively easy to use and gives a good correlation. This method correlates ash viscosity in the true liquid range to the factor

$$\frac{SiO_2 \times 100}{SiO_2 + Fe_2O_3 + CaO + MgO}$$

In this paper this factor is designated as the "equivalent silica percentage." In the true liquid range all slags having similar equivalent silica percentages will have a similar viscosity-temperature relationship. Based on experimental data a family of logarithmic curves can be established showing the viscosity-temperature relationship for a range of equivalent silica contents. Such a series of curves is shown on Fig. 4.

While this method may appear to neglect the effect of alumina, this is not exactly true. Measured viscosities show that as alumina replaces silica in a slag analysis, the viscosity decreases. Also as alumina replaces silica the calculated equivalent silica percentage lowers, which also means a lower calculated viscosity. Hence this method does in reality compensate for changes in alumina

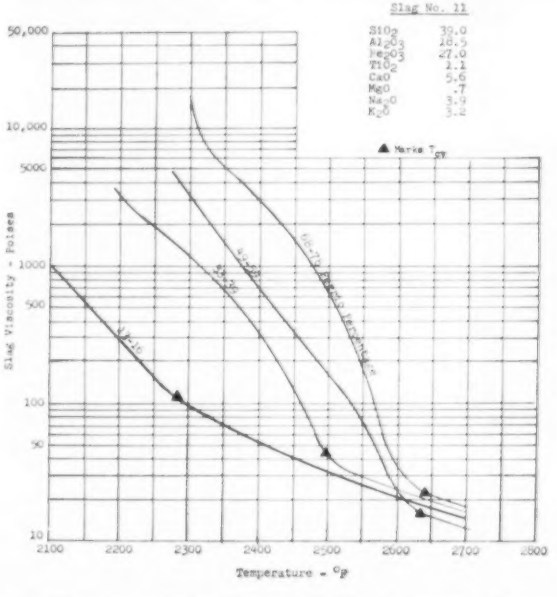


Fig. 5—Viscosity-temperature plots of a typical slag showing effect of ferric percentage

content. This method holds reasonably well for silica to alumina ratios from 1 to 4.

Point of Critical Viscosity. Measured viscosities of many slags show that, as the slags are cooled, viscosity increases uniformly along a line approaching that calculated as above. It will be recalled, however, that as cooling proceeds, a point may be reached where viscosity increases more rapidly as a drop in temperature takes place. This is caused by a selective separation of solid material from the liquid. Many authorities refer to this as the start of crystal formation. Limited attempts to identify material in the viscometer melt have proved generally unsuccessful, since most of the material is non-crystalline. However Fe_2O_3 and $4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ have been identified by X-ray defraction in a melt from a coal ash high in calcium and iron. Nevertheless, the separation of the solid material is a real phenomenon and in many cases can actually be seen.

The point at which this separation of solid material begins is not always sharply defined and may occur at higher temperatures by extremely slow cooling rates. For the work covered in this paper, all slags were cooled in steps of 30 deg over a period of 30 min except in zones where rapid changes in viscosity occurred. At each step viscosity was observed for 5 min to determine if a change was taking place. This cooling rate is considered slower than the chilling of slags during their passage from the combustion zone to the slag tank.

The point at which the temperature of critical viscosity occurs is dependent largely upon the iron content of the slag and on the degree of oxidization of the iron. The degree of iron oxidization is normally expressed as the ferric percentage where

$$\text{Ferric percentage} = \frac{Fe_2O_3}{Fe_2O_3 + 1.11\ FeO + 1.43\ Fe} \times 100$$

In stating the viscosity of a slag containing iron it is of prime importance that the degree of oxidization, ferric percentage, be expressed. Fig. 5 shows viscosity curves for a typical slag run under various stages of oxidization. Note that, in the tapping range of 50–100 poises, ferric percentage has a very marked effect on viscosity. In making viscosity determinations, therefore, it is not sufficient to know the type of atmosphere in which the determinations were made, but samples must be periodically taken to determine ferric percentage, and the atmosphere must be adjusted to obtain the desired ferric percentage.

Samples of slags from a large number of slag tap furnaces operating under normal conditions at 10–15 per cent excess air show an average ferric percentage of 20. Bureau of Mines data (4) also show approximately a 20 per cent ferric average with a range of 6–34 per cent on 16 pulverized fuel units that they investigated. Hence a means of predicting the temperature of critical viscosity and the apparent viscosity below this temperature at 20 per cent ferric is desirable. We find that the ash softening temperature in a reducing atmosphere (hemispherical point) plus 200 F gives a fair approximation of this point for the purpose for which it is used. Fig. 6 shows a plot of actual determined temperatures vs. ash softening temperature in a reducing atmosphere plus 200 F from data on Table I. There is reasonable agreement with the T_{cv}. Some of the discrepancy results from the determination of T_{cv} at other than 20 per cent ferric. After

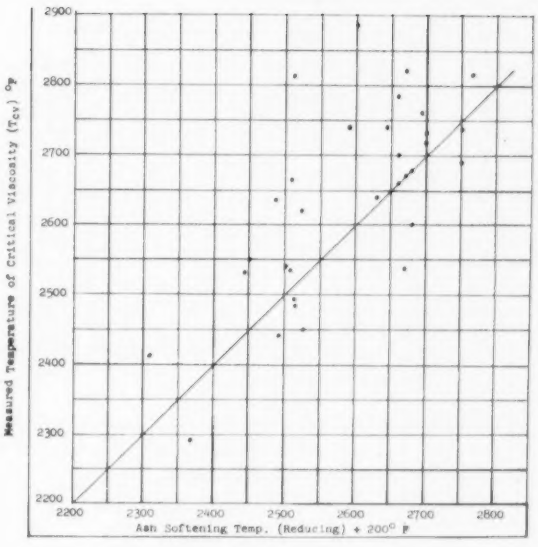


Fig. 6—Comparison of measured T_{cv} with calculated at 20% ferric

the T_{cv} has been established it can be located on the liquid viscosity line on the plot as shown on Fig. 4. If this point falls below 250 poises, extending a line upward at a 10 deg slope gives a reasonable approximation of the temperature-viscosity relationship up to 250 poises. An example of how this is applied is shown on Fig. 4. Figure 7 shows an approximate method of correcting temperature for other than 20 ferric percentage to 20 per cent at 50, 100, and 250 poises viscosity.

A comparison of viscosities as obtained by this method with actual measured viscosity corrected to 20 ferric percentage is shown on Fig. 8. With very few exceptions the predicted viscosities fall within a band of plus or minus 100 F from measured values.

Base-to-Acid-Ratio-Method

The constituents of a coal ash can be classed as either basic or acidic. The acidic constituents are the silica, alumina, and titania. The basic constituents are the iron, calcium, magnesia, and alkalies. For coals mined in the U. S., the acid materials almost always exceed the basic. The relative amounts of the basic and acidic constituents in the ash can be used as a means of predicting the viscosity of the slag and also as a means of determining what substances must be added to the ash to obtain desired flow characteristics. These values can be expressed as the base-to-acid ratio, which is defined as:

$$= \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

The viscosity of a slag decreases as the base-to-acid ratio increases to 1. Although our investigation beyond this point is limited, other investigators indicate that viscosity is fairly uniform at base-to-acid ratios between 1 and 8 (6).

The slag temperature for any given viscosity can be plotted against the base-to-acid ratio. Plots for 50, 100, and 250 poises are shown on Figs. 9, 10, and 11. In slags having a low base-to-acid ratio, the temperature required for a given viscosity increases more rapidly as the silica-

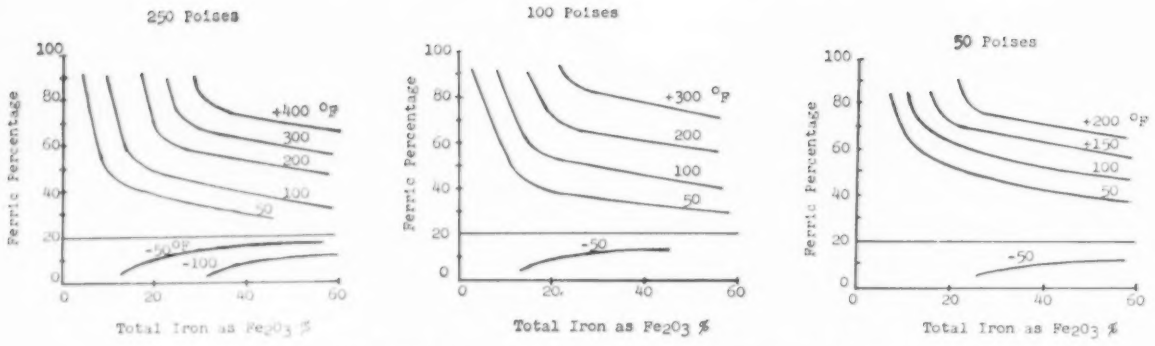


Fig. 7—Amount of change in temperature at a stated viscosity at other than 20% ferric

to-alumina ratio becomes higher. Ranges for a silica-to-alumina ratio below 1 have not been investigated; however, this trend is expected to reverse as the alumina content exceeds that of the silica.

A comparison of viscosities as obtained from the curves on Figs. 9, 10, and 11 with the actual measured viscosity when corrected to 20 ferric percentage is shown on Fig. 12. The viscosities predicted by the base-to-acid ratio show about the same accuracy as the modified Bureau of Mines method.

Only a limited amount of work has been conducted on slags where the potassium or magnesium content was of sufficient magnitude to permit evaluating their effect in relation to other basic constituents. Care should be used in extending these curves to slags containing major proportions of these two materials. Other authorities (7, 8) have suggested using multiplying factors for the individual elements. However within the range found in U. S. coal-ash slags we find this does not appreciably improve the correlation.

Fluxing

Under certain conditions a slag may be altered to obtain desired flow characteristics. Fluxing or blending of slags to lower viscosity is generally effective; however, an increase in viscosity by the addition of materials is not so readily attained. In order to be completely effective all materials in the base slag and the added material must be intimately mixed and melted.

Figs. 9, 10, and 11 offer a means of predicting the effect of altering a slag by the addition of a flux or as a result of blending with other slags. The weights of the respective materials in the resulting mix are calculated and the new base-to-acid ratio obtained. Values of materials added should be expressed as oxides. The resulting temperature for 50, 100, and 250 poises at 20 ferric percentage can be read directly from the charts.

The selection of a flux is usually dictated by economic reasons. In many cases the materials to be used in this way may be available locally in nature or as waste materials. The following is offered as a guide in selecting a flux.

Calcium Compounds. This is the most common type of flux and is usually obtainable in the form of limestone ($CaCO_3$) or as the hydroxide ($Ca(OH)_2$).

Iron Compounds. Mill scale or other high iron compounds may effectively be used as a flux; however, they usually command a premium price. Iron or iron compounds tend to separate from the slag under adverse operating conditions, hence some care should be exercised in their use.

Magnesium Compounds. Magnesium compounds are very similar to calcium in fluxing ability. Manufactured magnesium compounds are usually costly. However, many localities have natural deposits of dolomite or dolomitic lime,which are suitable fluxes.

Sodium Compounds. Sodium compounds are very effective fluxes and are often used in the form of soda ash (Na_2CO_3) or salt cake (Na_2SO_4) for emergencies. Published literature indicates that sodium compounds probably contribute to boiler fouling, hence their continuous use is not desirable.

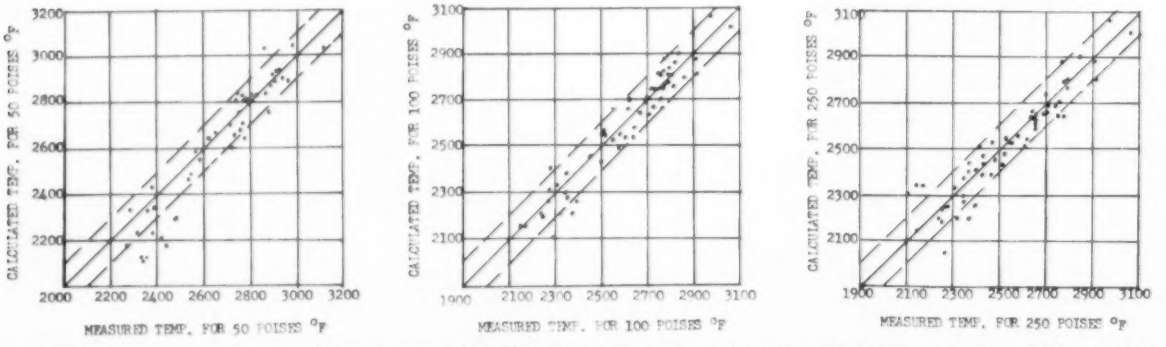

CALCULATED TEMP. FOR 50 POISES °F
MEASURED TEMP. FOR 50 POISES °F
CALCULATED TEMP. FOR 100 POISES °F
MEASURED TEMP. FOR 100 POISES °F
CALCULATED TEMP. FOR 250 POISES °F
MEASURED TEMP. FOR 250 POISES °F

Fig. 8—Plot of temperatures for measured viscosity corrected to 20% ferric vs. viscosity as calculated by modified bureau of mines method at 50, 100 and 250 poises

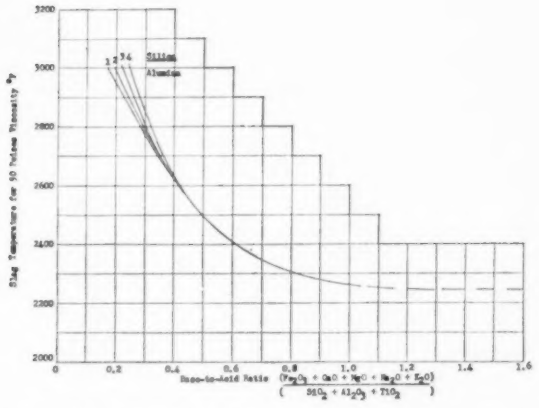


Fig. 9—Plot of temperature for 50 poises viscosity at 20% ferric vs. base-to-acid ratio

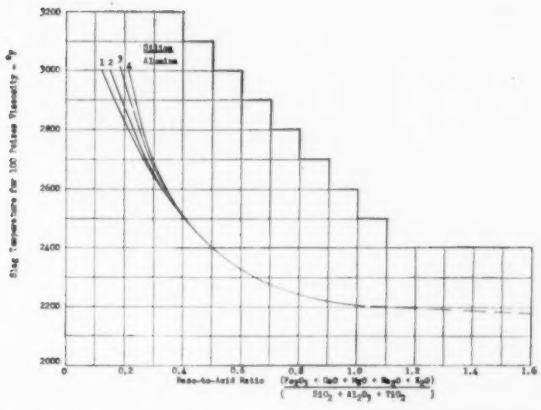


Fig. 10 Plot of temperature for 100 poises viscosity at 20% ferric vs. base-to-acid ratio

Potassium Compounds. The effect of potassium compounds on slag viscosity has not been investigated to any extent. They are not considered as effective as the other compounds listed. Some authorities (8) suggest that in certain cases they may increase viscosity.

Ash Blending. A high viscosity ash and a low viscosity ash can often be blended to obtain more desirable flow characteristics. One practical application of this is to fire wood and bark in combination with coal. Most wood and bark ashes have a high calcium content, which will appreciably lower the viscosity of the coal slag.

Conclusions

The goal of this paper has been to show how laboratory analysis of a coal and its ash can be practically and reliably used to predict the slag behavior in the furnace of a power boiler. This information is of pertinent value to the boiler manufacturer in the design of his equipment, to the boiler operator in comparing and selecting the most suitable fuel sources and to the coal producer in determining the suitability of his fuel for use in the specified equipment.

A method has been shown whereby:

(1) The behavior of a slag in the tapping range can be defined by its temperature-viscosity relationship.

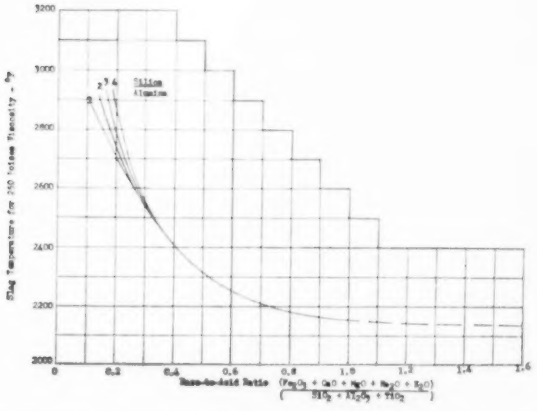


Fig. 11—Plot of temperature for 250 poises viscosity at 20% ferric vs. base-to-acid ratio

(2) Viscosity limitations on a known boiler design can be established.

(3) Viscosity-temperature relationship of an ash can be delineated in the tapping range from the chemical analysis and fusion temperatures.

(4) An unsatisfactory ash may be altered and the flux requirements predicted to obtain the desired viscosity-temperature relationship.

Through these means, therefore, it is possible not only to match flow characteristics with ash analysis but also to modify these characteristics to suit the requirements of a given design, whenever this proves economical.

Appendix

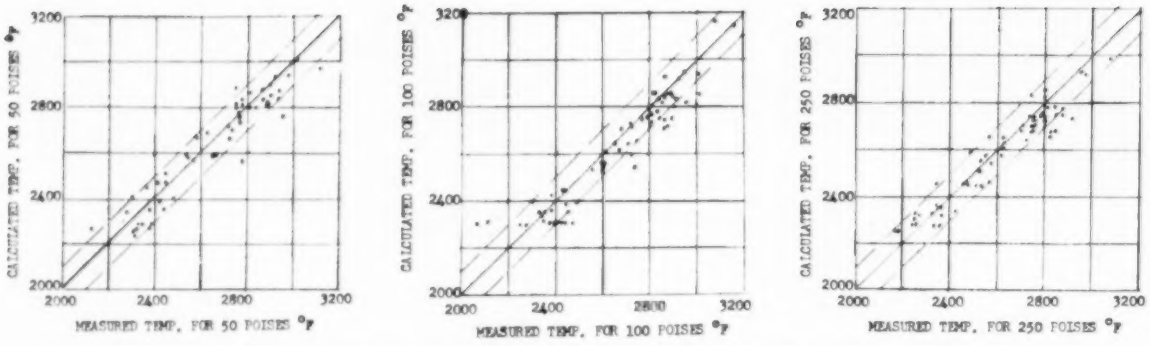
The viscometer used for this work is of the rotational type as illustrated on Fig. 13. The liquid under study is contained in a platinum-rhodium crucible, cylindrical in shape, and the cylindrical bob is rotated in the liquid at a constant speed through a calibrated suspension wire. The torque or amount of twist produced in the suspension wire is proportional to the viscosity. The amount of twist is measured and recorded as the interval between impulses from light beams reflected from mirrors attached to the ends of the wire. The strip chart recording of the twist, as shown on Fig. 13, provides a convenient record and method of measurement. The suspension wires used are calibrated against viscosity standard oils obtained from the Bureau of Standards and a glass measured and supplied by the Corning Glass Company.

The electrically heated furnace is of the Globar tube type with temperature regulation provided through a controlling type potentiometer actuated by a thermocouple located in the furnace adjacent to the sample crucible. A thermocouple imbedded in the slag crucible support serves to indicate sample temperature.

The ash sample, 150–200 g minimum, is prepared by standard laboratory methods and pelletized. Sufficient pellets are fed into the platinum crucible to obtain the desired slag level.

Atmosphere Control

Since the oxidization level of the iron in the slag has a marked effect on viscosity it is necessary to control the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MEASURED TEMP. FOR 50 POISES °F
CALCULATED TEMP. FOR 100 POISES °F
MEASURED TEMP. FOR 100 POISES °F
CALCULATED TEMP. FOR 250 POISES °F
MEASURED TEMP. FOR 250 POISES °F
2000
2400
2800
3200

Fig. 12.—Plot showing correlation between measured viscosity and calculated viscosity at 20 ferric percentage for base-to-acid ratio method

ferric percentage in the slag. This is accomplished by holding a hydrogen-nitrogen atmosphere over the surface of the melt. The ratio is varied to give the desired ferric percentage. A mixed gas flow of 0.5 cfh containing hydrogen, after passing over heated copper to remove any oxygen and then dried, is required to hold about a 20 ferric percentage level.

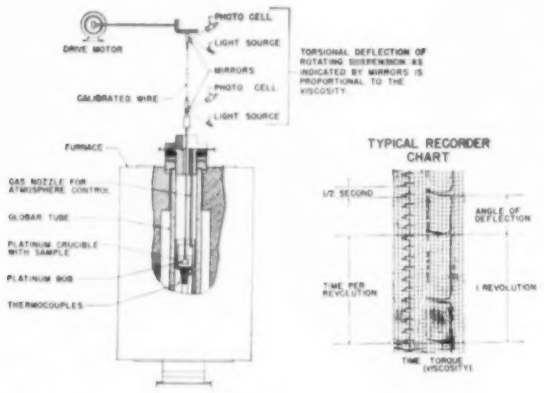

Fig. 13—Rotational type viscometer employed in the testing work the authors describe

Ferric percentage is determined periodically from samples taken from the melt by inserting a heavy platinum wire. The wire is withdrawn and plunged into water to prevent any oxidation and to break off the slag.

The ferrous iron and total iron contents of the slag sample are determined by standard analytical methods and the ferric percentage is calculated.

Test Procedure

After the sample is heated to well above true liquid temperature and the desired ferric percentage level obtained, the slag is cooled in controlled steps of 30 F over a 30 min period and viscosity determination made at each step. When changes in viscosity are very rapid, cooling may be in smaller steps. Several calibrated suspensions are required to cover the range of 0–10,000 poises viscosity.

The normal viscosity determination including analysis requires about 80 man-hours.

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(6) "The Development and Practice of Cyclone Firing in Germany" by H. Seidl. Published by the Institute of Mechanical Engineers, London, as advanced copy of paper given at joint conference on Combustion, 1955.

(7) "Viscosity Studies of System CaO-MgO-Al_2O_3-SiO_2" by J. S. Machin, D. L. Hanna, and Tin Boo Yee. A series of four (4) papers published in *Journal of the American Ceramic Society:* Vol. 28, No. 11 (1945), pp. 310–316; Vol. 31, No. 7 (1948), pp. 200–204; Vol. 35, No. 12 (1952), pp. 177–186; Vol. 37, No. 4 (1954), pp. 177–186.

(8) "Relations Between Chemical Composition and Viscosity of Liquid Coal Slags in Melting Furnaces." Papers I and II by K. Endell and D. Zauleck published in *Bergbau und Energiewirtschaft*, 1950, Vol. 3, No. 2 and 3, pp. 42–50, 70–73.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part XIII

More About Anti-Flash Baffling

By IGOR J. KARASSIK* — Worthington Corp.
L. E. ZABEL† — Worthington Corp.
E. K. HESS‡ — Gilbert Associates, Inc.

THE Steam Power Plant Clinic—VIII published in the May 1959 issue of COMBUSTION dealt with the subject of anti-flash baffling in deaerating heaters. This construction, which first appeared in the early 1940's and became quite popular in steam-electric generating stations from 1945 on, was later found to be actually of relatively little help in protecting boiler feed pumps from the ill effects of sudden drops in turbine loads. Even this help, it appeared, came too late to be really effective.

Since the publication of that article new information has become available which indicates that not only can the effects of anti-flash baffling be characterized by the expression "too little and too late," but that this construction can become downright dangerous under certain circumstances. Specifically, two separate cases have come to our attention where anti-flash baffling appears to have been instrumental in promoting flashing instead of preventing it. In both cases, operation was apparently satisfactory whenever the sudden load drop took place after many hours of operation and after the storage feedwater had reached normal saturation temperature. But whenever the load drop took place shortly after a cold start-up, the flashing extended into the suction piping and caused serious and dangerous vibration in this piping.

Operating Theory

It may be well to review very briefly what had been said on the subject of anti-flash baffling in the May 1959 issue of COMBUSTION. Immediately following a sudden turbine load reduction the check valve between the turbine extraction stage and the deaerating heater closes. From that moment on, under the influence of the withdrawal of hot feedwater from the deaerator and of the entrance of cold condensate into the deaerator, the pressure in the deaerator decays rather rapidly. Of course, the temperature of the newly deaerated feedwater is reduced correspondingly. Unfortunately this colder feedwater does not reach the boiler feed pump suction until some time later. But since the pressure at the pump suction reflects the pressure reduction in the deaerator instantaneously, there arises the possibility that the resultant suction pressure will be insufficient to prevent flashing in the pump or even in the suction piping itself.

The principle of the anti-flash baffling (see Fig. 1) was based on leading the newly heated feedwater, which is at a temperature lower than the feedwater in storage, directly to the outlet from the storage space. The May 1959 article went on to show that while this was quite true no benefit could be obtained from this colder feedwater until the entire suction piping had been voided of the feedwater it contained immediately prior to the load reduction. By that time, the article went on to prove, the worst was over and normal conditions would soon be re-established—whether the deaerator was, or was not, provided with anti-flash baffling.

But all of this analysis was predicated upon the assumption that the storage space of the deaerating heater contained feedwater at a saturation temperature corresponding to the pressure in the deaerator. Under these conditions as soon as the slightest reduction in pressure occurs, flashing occurs at the surface of the feedwater in the storage space. The steam thus liberated acts to retard the decay in pressure in the heater.

If, on the other hand, the feedwater in storage is at a temperature considerably below the saturation temperature, a very substantial drop in pressure must occur in the deaerator before any feedwater flashes into steam and acts to retard any further pressure decay. This substantial drop in pressure which will now take place almost immediately after the drop in turbine load will act very unfavorably upon the suction conditions at the boiler feed pump suction.

Field Experience

One of the two cases we referred to previously took

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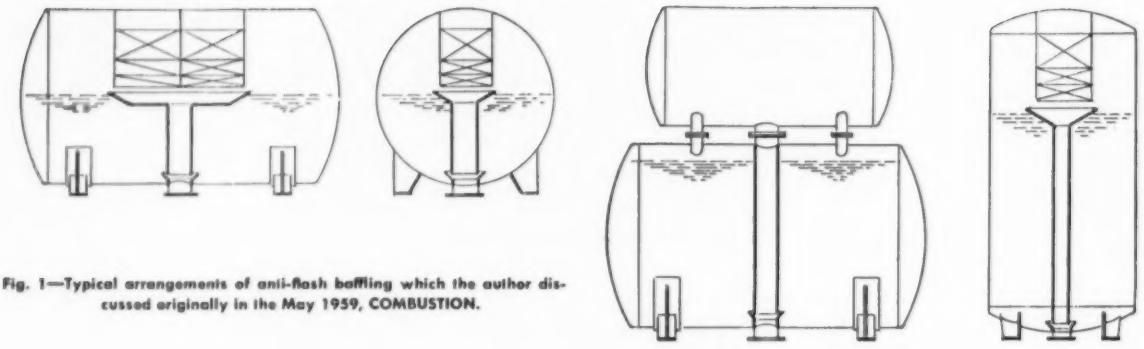

Fig. 1—Typical arrangements of anti-flash baffling which the author discussed originally in the May 1959, COMBUSTION.

place in a recently completed Japanese Power Plant. Steam-electric plants in Japan operate under a number of conditions which are somewhat more severe than those normally encountered in plants in the United States. The factors which differentiate these Japanese power plants are the following:

(1) Since hydroelectric power provides a large portion of the demand and they are run-of-river units, steam plants are operated to take all load variations.

(2) There is a very sharp and a very frequent variation in loading.

(3) Electrical storms cause a high frequency of partial and complete loss of load.

Because of the severity of these operating conditions, the Japanese Government imposes some very stringent tests on all new steam electric installations before they can be accepted and incorporated into the overall system. One of these tests requires that a new unit be rapidly brought up to full load and then suddenly tripped out.

It was during such a test that it was determined that standard anti-flash baffling, which directs freshly heated and deaerated water to the boiler feed pump suction instead of drawing upon the deaerator storage, can be the cause of severe cavitation and potential pump damage.

When the unit is brought up to full load rapidly the temperature of the water in the storage space lags behind the temperature of the water flowing to the boiler feed pump. Observations made during tests showed, for instance, that by the time the unit was at full load the water in the storage space was about 35 F below the deaerator saturation temperature. But since the deaerator was equipped with anti-flash baffling, the feedwater in the pump suction line was right up to saturation temperature.

Within seconds after the test trip-out, the boiler feed pumps lost suction and contact was made between running and stationary parts. But other tests carried out after a time intervals, such that the stored feedwater was at saturation temperature, indicated that such a violent pressure decay did not take place.

A study of this problem indicated that under normal operating conditions and with storage up to saturation temperature, the *actual* rate of pressure decay in the deaerator would not exceed the *allowable* rate. But if the feedwater in the storage space was 35 F below saturation, the deaerator pressure would have to drop about 35 psi before flashing in the storage would help moderate the rate of pressure decay. As a result, this 35 psi pressure drop was almost instantaneous, while it took approximately 30 seconds for the water in the suction line to get through the pump. Since the system did not have 80 feet (equivalent to 35 psi) excess NPSH flashing took place in the line.

Suggested Design Modification

It was decided that in order to prevent the temperature in the pump suction line from being higher than that in the storage space, the anti-flash baffling will be so modified as to prevent the direct flow of water from the deaerating section into the pump suction line. Instead, this flow will be permitted to mix thoroughly with the water in the storage space so as to quickly bring this water right up to saturation temperature.

While it is true that conditions in Japan may be somewhat different from those normally encountered in the United States, the authors feel that this problem should bring about a complete re-evaluation of the use of anti-flash baffling similar to that shown on Fig. 1. As a matter of fact, certain trends and developments in the United States act to affect the influence of this baffling in the same direction as that encountered in Japan.

(1) As a result of improved deaerator design and of the higher operating deaerator pressures, the ratio of deaerator shell volume to its rated capacity is being gradually reduced. This means that there is less residual steam for the condensate to condense at the instant of trip-out.

(2) As the size of units increases so does that of the storage tank. This, along with the increasing number of outdoor installations, means that there is a greater chance that the storage tank temperature will be under the saturation temperature corresponding to the deaerator operating pressure. This is particularly true when a trip-out occurs after a sudden increase in load.

(3) There is an increasing practice of withdrawing some saturated steam from the deaerator shell for building heating. This helps to increase the rate of pressure decay and becomes very critical when storage temperature is below saturation.

(4) Larger size units require large capacity boiler feed pumps and higher values of NPSH. If booster pumps are not used to provide artificial additional NPSH, the margin between the available and required NPSH is being constantly narrowed.

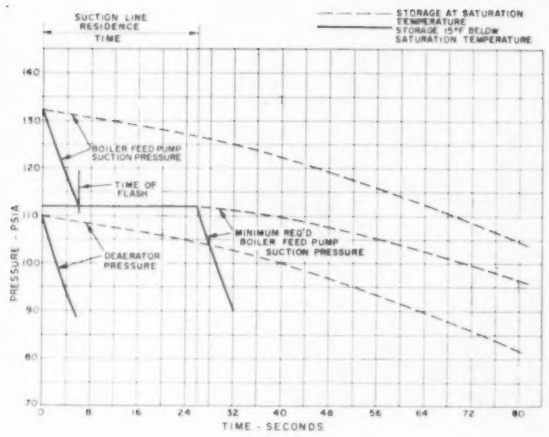
SUCTION LINE RESIDENCE TIME
STORAGE AT SATURATION TEMPERATURE
STORAGE 15°F BELOW SATURATION TEMPERATURE
BOILER FEED PUMP SUCTION PRESSURE
TIME OF FLASH
MINIMUM REQ'D BOILER FEED PUMP SUCTION PRESSURE
DEAERATOR PRESSURE
PRESSURE - PSIA
TIME - SECONDS

Fig. 2—Dotted line curves above depict an absence of any problem—deaerator pressure decays slowly and never falls below feed pump pressure—if stored water is allowed to reach saturation temperature before trip-out. The solid line curves indicate a different situation with stored feedwater 15 F below saturation. Within 6 seconds after trip-out pump pressure falls to where flashing occurs.

(5) Today's base loaded unit is tomorrow's peaking unit.

A similar case was brought to our attention which involved a 175 MW installation with a deaerator operating under the following conditions:

Outlet capacity	1,300,000 lb/hr
Operating pressure	110 psia
Condensate inlet flow	910,300 lb/hr
Condensate temperature	264 F
Feedwater outlet temperature	334.7 F
Steam to auxiliaries	25,000 lb/hr Max
Storage capacity	25,000 gal
Total internal volume of deaerator shell	1175 cu ft

The unit is served by high speed boiler feed pumps which are preceded by single stage, low speed booster pumps with a required NPSH at full load of 6 feet. The residence time in the suction piping is 26 seconds under full load conditions.

Difficulties encountered at the previously discussed plant resulted in a very thorough study of this installation. Fig. 2 illustrates what takes place following a trip-out under two different conditions. Under the first condition, it is assumed that the temperature in the deaerator storage is at saturation (curves shown in dotted lines on Fig. 2). The calculations were carried out using a point-by-point heat balance, rather than a short-cut method. The deaerator pressure decays rather slowly and, because there is such a liberal margin over the required NPSH, the line of boiler feed pump suction pressure never intersects the curve of the minimum required suction pressure. This latter is constructed by assuming that the flow to the boiler is not reduced immediately to the value of the steam flow, but rather continues at the full load capacity by virtue of the boiler shrinkage and the corresponding action of the feedwater regulating mechanism. Thus, no problem will exist if the stored feedwater has reached saturation temperature.

However, if we assume that the stored feedwater is 15 F below saturation, the pressure decay curve in the deaerator is considerably more rapid (solid lines on Fig. 2). Within 6 seconds after the trip-out, the boiler feed pump suction curve intersects the curve showing the minimum required suction pressure and flashing will have taken place.

Conclusions

The conclusions reached in these studies were that the anti-flash baffling should be entirely eliminated or a distribution pipe installed to direct newly heated and deaerated water so that it will be distributed in the storage shell to bring the stored water up to maximum temperature as quickly as possible and so that the boiler feed pump would receive the lowest temperature water.

The authors feel that this analysis has helped demonstrate that while standard anti-flash baffling can give very little help when storage is at saturation, it can easily become a booby trap and lead to most dangerous results whenever a trip-out follows a cold start or a rapid increase in turbine load. It appears that if any baffling is used it would be better to promote mixing of storage rather than retard it. This should help to confine the unavoidable flashing (which could take place during load reduction) to the liquid in the deaerator storage space rather than in the pump.

Dresden Station Goes Critical

The reactor for the USA's first full-scale, privately-financed nuclear power station sustained its first chain reaction the 15th of October, 1959 at 2:45 a.m. according to the General Electric Co. and the Commonwealth Edison Co.

Criticality was reached after engineers placed the 28th fuel element in the reactor core. When completely loaded, the core will contain 488 such elements.

General Electric designed and built Dresden for the Commonwealth Edison Company and the cosponsoring Nuclear Power Group, Inc.

Triggering of the first Dresden chain nuclear reaction was accomplished by withdrawing a number of the plant's 80 stainless steel control rods a predetermined distance out of the bottom of the core.

Movement of the rods, containing 2 per cent boron to increase absorption of neutrons, was regulated from a central control room.

Twentieth Annual Water Conference

THE Twentieth Annual Water Conference sponsored by the Engineers' Society of Western Pennsylvania scheduled for October 26–28, 1959, was held at its usual site, the Penn-Sheraton in Pittsburgh. Attendance was close to the 500 average of the last several years. A very enjoyable "get-together" party was employed to salute this highly regarded annual affair. Below we present abstracts of the papers we hold to be of interest to the COMBUSTION reader.

Ion Exchange Progress

W. S. Morrison and **Joseph Thompson,** Illinois Water Treatment Co., opened the technical phase of the program with the paper "Twenty Years of Progress in Ion Exchange." Here are their selections of the ten most important developments of the past twenty years in the field of water conditioning by ion exchange.

(1) Organic Cation Exchange Resins: The availability of organic type cation exchange resins permitted regeneration of the materials not only with salt but also with acids; i.e., operation on the hydrogen cycle. Thus, the passage of water through the hydrogen form of the cation resin resulted in the conversion of salts to their respective acids. When the effluent of the hydrogen unit was blended in proper proportion with the effluent of a sodium cycle cation unit operating in parallel with the hydrogen cycle, and the carbon dioxide generated in this technique was removed by degasification, a softened water of controlled alkalinity and reduced solids content was produced. This split stream dealkalization technique was applied to advantage to the treatment of selected water supplies.

(2) Weakly Basic Anion Exchange Resins: These materials, in the authors' opinion, made possible for the first time the deionization of solutions. The original granular materials could be regenerated with an alkali such as soda ash, caustic and ammonia and in use, the hydroxyl ion of the resin could be substituted for chlorides, sulfates, phosphates and nitrates of a water supply. However, the materials were insufficiently strongly basic to permit the exchange of weakly ionized constituents such as silica and carbon dioxide. Over the years other materials have been developed overcoming this.

(3) Strongly Basic Anion Exchange Resins: When resins of this type were introduced in 1948, deionizing of makeup water for high pressure boilers became a practical reality. These materials were sufficiently strongly basic to permit the exchange of weakly and strongly ionized constituents. Thus, carbon dioxide and more importantly silica removal was accomplished in a two-step, cation-anion treatment.

As with any new development, not only did the strongly basic anion resins expand the field of ion exchange, but with this expansion came new problems. One of the more difficult and persistent problems has been the tendency of strongly basic anion exchange materials to become fouled with long chain high molecular weight organic materials found in surface water supplies. Porous type strongly basic anion exchange resins alleviated the problem somewhat.

In boiler feedwater applications, the authors stated, residual silica rather than specific resistant readings should be used to fix the endpoint of an operational cycle. Because it is not possible to predict with complete accuracy the potential anion resin fouling characteristics of a surface water supply, the best approach where large quantities of water are to be handled lies in pilot plant investigation prior to full plant scale installation.

(4) Hot Lime—Sodium Cycle Exchange: The years of experience indicated styrene type high capacity cation exchange resins were very stable materials. They exhibited excellent stability at temperatures as high as 250 F and pH values as high as 11.0, so that it was soon decided to take advantage of these resin characteristics by installing a cation unit operating on the sodium cycle after a hot process softener using lime as the precipitating agent. This combination of hot process precipitation and hot cation exchange softening presented a number of advantages over the previously used combination hot lime-soda supplementary phosphate treatment.

(5) Chloride Anion Exchange Dealkalization: Under normal conditions, the authors pointed out, strongly basic anion exchange resins are used in the hydroxyl form to adsorb negatively charged ions from acids, from neutral salts and even mildly alkaline solutions. However, when these resins are regenerated with salt they are converted to the chloride form and, under proper conditions, the chloride ions can be exchanged for bicarbonates, sulfates and even fluorides and sulfides of a water supply. Although the equilibrium conditions for the adsorption of these ions are not entirely favorable because of the greater affinity of the chlorides for the resin, the exchange is sufficiently complete to render practical this treatment method. In fact, the use of salt as a neutral, inexpensive regenerant is so attractive that chloride anion exchange dealkalization has generated rather widespread interest in, low pressure plants.

(6) Mixed Bed Deionization: In a mixed bed deionization unit the cation and anion resins are, as the name implies, mixed intimately in a single reactor vessel. If the cation and anion resins are mixed in a ratio of one to one, then we can assume that the bed consists of alternate cation and anion particles. If each of these

particles is visualized as an individual unit, then a mixed bed may be regarded as a multiple bed deionizing system consisting of countless numbers of cation and anion exchange columns arranged alternately in series.

The ultimate in removal of cations is obtained with the mixed bed technique, as is also the case for silica removal. Ionized silica residuals of less than 0.01 ppm can be obtained at economic regeneration levels in a mixed bed unit.

(7) Counterflow Regeneration: In the normal operation of a two-bed deionizing system leakage of sodium ions from the cation exchange unit has always been a problem. Leakage of ions is due to the fact that residual contaminating cations are never removed completely from the resin column when using the normally practiced down flow regeneration technique. Rather, these objectionable ions are pushed down to the bottom-most portion of the bed.

Counterflow regeneration of ion exchange columns involves the passage of regenerant upwardly through the resin. At the same time that acid is introduced at the bottom of the unit, water is introduced at the top of the column and both of these flows are drawn off through the distributor located at the top of the bed. Thus, the upward flow of regenerant is counterbalanced by the downward flow of water and the expansion of the resin bed is prevented. Further, ion leakage is reduced appreciably because the treated water passes through the most completely regenerated portion of the resin bed immediately prior to its withdrawal from the exchanger column; calcium sulfate precipitation potential is practically eliminated; exchange capacity is increased.

(8) Automation of Ion Exchange Equipment: The ion exchange equipment industry has been keeping pace with the general trend throughout all industry toward automation of equipment. It is now possible to obtain equipment over a whole range of flows and capacities designed to backwash, regenerate and rinse completely equipment over a whole range of flows and capacities designed to backwash, regenerate and rinse completely automatically with the start of the operational cycle actuated by push button or from an impulse received from a flow meter or conductivity instrument.

(9) High Flow Rate Exchange: Although deionization has now long been recognized as an excellent means for preparing makeup water for power generators, until recently little interest was shown in the need for condensate treatment where small amounts of impurities are present and the water volume extremely large. However, with the advent of mixed bed deionization the removal of even minute concentrations of ions was found to be practical.

Pilot plant work commenced in 1956 has established that flow rates as high as 100 gpm per sq ft on full flow condensate demineralizers are feasible. Water of extremely high quality is obtained; the units can be regenerated successfully in place; and the capacity of the resins for this operation are more than ample.

(10) Continuous Ion Exchange: Although this new development may not be most effectively applied to the treatment of normal water supplies, continuous ion exchange must find a place on any "Best 10" list.

In a continuous ion exchanger the resins are pulsed through a loop in which certain zones are devoted to the regeneration, rinse and service steps. In essence, the continuous ion exchanger moves resins through a column of liquid rather than having a liquid move through a column of resins. Thus, the continuous counterflow operation is obtained without sacrifice of through-put and exchange efficiency.

The authors supported their selections with an excellent list of references which were made a part of the written paper.

Water Clarification

The problems of "Design Considerations and Operating Experiences in Clarification of High Color—Low Turbidity Waters" were discussed in a two-paper session led off by **E. A. Strahlendorff,** Graver Water Conditioning Co.

Practical experience with coagulation of this type water, according to Mr. Strahlendorff, indicates the selection of treatment chemicals is a limited one. Generally they consist of a coagulent, usually alum, but occasionally an iron salt, a pH adjuster such as lime or soda ash, and often a coagulent aid such as activated silica or Separan. Further, the optimum chemical treatment should be selected in the basis of thorough laboratory and field tests. In this way the settling rates of the flocs formed by the treatment chemicals can be determined and a more accurate estimate of the size of clarifier required.

The selection of the clarifier size should be left to a consultant since there are many factors not supplied by field test data. Most prominent of these factors is the judgment of the degree of operator skill available. As a rough rule of thumb the upward rise rate is held to be the determinant for the diameter of a clarifier machine while the detention time sets unit height.

The author then discussed the advantages of adding chemical reagents, separately or together, feeding these chemicals at the clarifier or before, the merits of mixing provisions, and of sludge recirculation as well as excess sludge removal, and the provision for separate space for floc formation.

The difficulties of corrosion which can be expected with a water whose pH must be held below 7.0 came in for considerable attention. The standard preventives—coal tar base paints and enamels, alone or together with cathodic protective devices—were briefly discussed. The author then described installations in four plants of his company's Reactivator and gave data on the waters handled and the results obtained.

Following Mr. Strahlendorff's presentation, **C. T. Wise** of the J. E. Sirrine Co. spoke on "Experiences in Clarification of High Color, Low Solids Surface Water."

He indicated that high color, low turbidity surface water is one of the most difficult waters to clarify, saying that there is no modern, magic method for the engineer to use in solving the problem. The answer perhaps, in the refinement of established and proven methods in the water treatment field. Costs for treating this type of water are usually relatively high and should be very carefully evaluated.

Chemical treatment. One of the most important

unit processes, Mr. Wise said, is the use of the proper coagulants and of feed in coagulating high color water.

Experience at this and other plants indicates that where the color in the raw water does not exceed about 150 to 200 ppm provisions for feeding alum, lime, chlorine and one of the polyelectrolite coagulant-aids are usually adequate.

The points of feed of the coagulants should be given careful consideration. It is considered good practice to feed the coagulants into the raw water mixing chamber with the coagulant-aid being fed in the flocculation zone after the floc has begun to form. It is desirable to provide the chemical solution feed piping so that the feed of alum and coagulant-aid may be split, if desired, feeding a part into the raw water mixing compartment, and a part into the flocculation basin. Care should be taken that the chemicals are discharged into the basins at a point where short-circuiting will be minimized.

Mixing. Progressing to another unit process, it is believed that for treating high color water a separate flash mixing stage should be provided. This provides better assurance of thorough dispersion of the chemicals in the water before any floc is formed.

Coagulation. Mr. Wise also stated that coagulation is one of the most important stages in pretreatment especially of low-solids water. A detention in the flocculation zone of 40 to 60 minutes is desirable. For upflow, sludge contact type units it appears reasonable that a part of the sludge contact zone may be considered as a part of the flocculation stage. A gentle rolling agitation that will agglomerate and not disintegrate the floc is required. Violent agitation in any part of the basin should be avoided.

Sedimentation. The relatively difficult settling characteristics of the light color floc justifies a careful design of the sedimentation basins. It is of extreme importance that every reasonable precaution be taken to eliminate short-circuiting of flow through the basin. A step in the right direction is the equal distribution of the influent and the effluent across the full width of the basin normal to the direction of flow. Properly spaced submerged orifices have been found to be a successful method of distributing the flow into and from a basin.

The necessity of mechanical sludge removal is dictated by the type of settling basin and the rate of accumulation of sludge. Continuous sludge removal is usually desirable for water treatment plants for industries where the water demand is fairly steady and continuous for 24-hour days and 7-day weeks.

Filtration. In speaking of filtration the author said that an important factor in the design of filter beds is the rate of filtration. For a high color, low solids water it can be expected that, in spite of all precautions taken to properly condition the water before filtration, there are going to be times when some floc carryover to the beds will occur. In view of this it is thought that a reasonable design rate is 2.5 gpm per sq ft of bed, but that the hydraulic capacity should be 4.0 gpm.

Speaking of silica sand as a filter medium, the author described the effective size as 0.40 to 0.45 mm and the uniformity coefficient as less than 1.5. Sufficient backwash water is usually provided to give a sand expansion of 50 per cent. This generally requires a wash rate equal to a rise of 30 to 36 in. per min.

Water storage. Adequate storage capacity of the finished water is important for this type of treatment plant. It is believed that in order to minimize the effect on the plant of sudden changes a fairly constant flow rate of raw water is desirable.

Cooling Tower

"The Function and Design of Industrial Cooling Towers" was the subject matter for **M. V. Gruber,** Foster Wheeler Corp. The major emphasis of the paper was on ways and means of increasing the service life of industrial cooling towers. The author went down the line in the design of a cooling tower stressing the service features. For example, on "Design Considerations":

"Costly maintenance in many instances is a result structural design. The tower should be required to withstand a minimum wind load of 30 lb per sq ft based on a 100 mph wind. Earthquake forces should be taken into account in locations where they apply. In addition, a live load of 60 lb per sq ft on the fan deck and 25 lb per sq ft on the filling is recommended. The design of the tower framing should be based on the wet weight of the lumber and include the water in the distribution system. The dry weight should be used in determining uplift forces. Members should be sized on the basis of actual and not nominal dimensions. Nails should not be used on any joint contributing to the strength or rigidity of the structure.

"Towers that operate continuously with hot water temperatures above 150 F require derating of the stress values assigned to the lumber. The values should be reduced in accordance with U. S. Forest Products Laboratory recommendations. For example, temperature may effect the tensile strength of lumber beyond 150 F up to $\frac{1}{2}$ per cent for each degree F. Chemical attack of lumber proceeds rapidly at elevated temperatures requiring careful control of water chemistry."

In much the same, factual, right-to-the point manner Mr. Gruber discussed framework, filling, sheathing, water distribution system, hardware, mechanical equipment and cooling tower maintenance.

D. R. Baker, Marly Co., took on the subject of "Physical Inspection of Cooling Towers." As he saw the inspection requirements they were twofold: (1) an understanding of the causes of wood deterioration; (2) the physical means of identification. Up until 1949 all deterioration of cooling tower lumber was held to be delignification implying chemical reaction similar to the process of making pulp. Microscopic examination in 1949 of such wood revealed wood destroying organisms.

The author did not feel a competent wood inspector needed to be a mycologist but he should be able to recognize the "classical" wood-destroyers. These Mr Baker cited as a rather small portion of the fleshy fungi which also includes toadstools and mushrooms. The molds make up a lower form of fungi and many of them can attack purer forms of cellulose such as paper or cotton cloth. Their wood damage has been called "soft rot" by the British. These wood-destroyers fall into two classes: the more common one in nature produces brown cubical rot and the other white pocket rot. This latter one is the most prevalent in cooling towers.

Earlier stages of attack can be detected by striking

the wood a sharp blow with a hammer. This may break through an otherwise solid seeming material. Sometimes just the feel of the hammer indicates a dull, hollow interior revealing that the wood has lost its resilience. An ice pick or probe is frequently used to detect internal attack although its recommended use is mainly for exploration of suspicious areas.

W. A. Dost, Californaia Redwood Association, then commented on "Certification of Redwood and Effect of Oxidizing Agents on Redwood." Mr. Dost's Association has two major programs underway: a quality control program, and a study of the causes of failure in cooling tower use. As a result there are printed aids to those purchasing redwood and the Cooling Tower Institute has developed specifications for cooling tower lumber. There is now, however, an industry program of inspection and the quality of tower lumber is maintained through self certification by manufacturers. The Association has released, however, an Interim Report N, available upon request, giving recommendations on circulating water treatment.

J. L. Willa, The Cooling Tower Institute, gave as his paper "Report on Field Wood Preservation Studies," a summary of the CTI Bulletin WMS-104, the Technical Sub-Committee No. 3's report on "Wood Maintenance for Water Cooling Towers."

This bulletin is an excellent one giving an introduction to the report which traces briefly the recognition in 1950 of the steadily growing occurrence of redwood deterioration in cooling towers. The report then records the formation of a study team by cooling tower manufacturers, the Institute and the Redwood Association.

The various types of deterioration are listed and helpful information given on each one in this CTI Bulletin. In addition, tables and performance curves are displayed for various chemical and deterioration preventatives for a number of the test cases reported.

Stainless Steel Condenser Tubes

Leading off the Monday afternoon session **E. R. Long** of the Monongahela Power Co. discussed "Experiences with the Use of Stainless Steel Condenser Tubes at the Rivesville Power Station." The Rivesville Station is located on the Monongahela River where coal mine drainage renders the cooling water highly corrosive. The 16 Bwg 88-10-2 copper alloy tubes in Unit 6 condenser were replaced in May 1958 after 6 $^{2}/_{3}$ calendar years of service at about 90 per cent service factor. The average wall thickness had been reduced to 0.020 in. and were approaching the point of possible mass failure.

In Monongahela Power Co. tests type 304 stainless steel had been found very durable but was not considered acceptable for a full condenser installation because of cost and reputed poor heat transfer characteristics. It had however, been used to fill the small section under the air baffles where copper alloys are subject to possible ammonia attack.

Comparison of copper alloy and type 304 stainless tubes after seven years service showed the copper tubes to have a tenacious layer of corrosion products on the water sides. The stainless tubes, however, had clean, bright steam side surfaces and seemed capable of being consistently cleaned by shooting nylon brushes once through each tube. The absence of corrosion attack on the steel tubes suggested the possibility of using thin walled steel tubes to offset relatively poor heat transfer characteristics and to take advantage of their better susceptibility to cleaning.

Average performance with copper alloy tubes, Mr. Long stated, is within the limits of 50 per cent and 60 per cent cleanliness factor. By current HEI standards 85 per cent clean 22-Bwg stainless tubes should nearly equal the performance of 60 per cent clean 16-Bwg 88-10-2 copper alloy tubes. Since Monongahela Power engineers believe that 22-Bwg stainless will last as long as thirty years, stainless tubes seemed a logical choice if cleaning could consistently recover to a cleanliness level of 85 per cent.

Stainless tubes were found to be easier to install and showed fewer than ten leaks after rolling. These few leaks were easily corrected.

The tests to determine the performance of the stainless tubes were conducted in exactly the same manner and with the same equipment as the tests previously run on copper alloy tubes.

Remembering that maximum average cleanliness with copper alloy tubes was 60 per cent and that 85 per cent was hoped for with stainless steel to achieve equivalent performance it was startling to hear that peak cleanliness performance with stainless tubes was 124 per cent and that average cleanliness is somewhere between 85 and 124 per cent.

In addition to longer life and improved turbine heat rate a corollary advantage was gained in that the stainless steel tubes have been found to be to some degree, self-cleaning. This cleaning results from the scouring action of sand and abrasive sediment in suspension in the river water. The amount of cleaning varies the amount of solids in suspension in the river caused by rains or passing boats.

Except for prolonged wet weather spells the stainless tubes will probably be cleaned as often as the copper tubes. However, Mr. Long told us there is one significant difference—the cost of cleaning the stainless tubes is consistently recovered by improved performance. This is not always true of copper alloy tubes.

A water velocity increase from the expected 6.5 fps to 7.5 fps showed improved performance and with further increases in velocity Mr. Long expects still lower turbine exhaust pressures. The system appears to average $^{1}/_{2}$ fps higher velocity with stainless tubes due apparently to lower system resistance than with copper alloy tubes.

Summing up Mr. Long said that experience to date shows that stainless tubes will produce equal or better turbine exhaust pressures than thick walled copper tubes under equivalent conditions. Assuming a practical method can be found to utilize the self-cleaning tendency of stainless tubes a condenser performance could be maintained at nearly maximum efficiency at all times and without loss of load during cleaning.

J. R. Maurer and **G. C. Kiefer** in their discussion of Mr. Long's paper mentioned several interesting points. They said that a clearer understanding of the increase in overall ability to conduct heat must come from:

1. Corrosion products and mineral deposits on the interior of the tubes.

2. These same films on the exterior surfaces.
3. The mode of condensation which occurs (drop or film).

In particular they stressed the fact that stainless steel resists wetting by condensed steam and this is necessary to produce dropwise condensation which several investigators have shown to assist heat transfer to a greater degree than film condensation. While type 304 stainless was used at Rivesville the discussers indicated that types 430 and 316 are also adaptable to condenser applications. Discussion further brought out the fact that in some condensers stainless steel tubes are installed around the outer periphery of the tube bundle to protect the softer tubes from the erosive impact of high velocity steam.

Since there has been some doubt about the use of stainless steel with copper alloy tube sheets the discussion indicated that while stainless steels are cathodic to brasses and bronzes, potentials are low and difficulties would not be expected.

Organic Fouling

J. K. Rice and **D. C. Simon II** of Cyrus Wm. Rice and Co. combined talents in presenting the paper "Organic Fouling in Anion Exchange." In the opening remarks the authors quickly identified organic fouling above all other types as the one of most concern. A series of laboratory investigations on service-fouled resins constitutes the background for the paper and has permitted the authors to advance certain hypotheses about the mechanism of fouling. The work presented closely parallels that of A. L. Wilson "Organic Fouling of Strongly Basic Anion-Exchange Resins" published in the *Journal of Applied Chemistry*, Vol. 9, July 1959, pp 352–359

Various tabular material produced, in the authors opinion, that a useful criterion of organic fouling may be the increase in strong basicity and decrease in weak basicity upon treatment with chlorides. Strongly oxidizing treatments can distort this picture. Test results were in substantial agreement with those of Wilson cited above, except that Wilson concluded that acid was relatively ineffective as a regenerant hot having tried concentrated HCl. This the authors did and found that concentrated HCl was by far the most effective single treatment in restoring strong basicity although it had almost no ability to restore total capacity. It appears to remove the maximum amount of adsorbed matter from the resins without damaging them.

In closing, the authors made this illuminating statement: "We have not attempted to present an answer to the fouling problems that accompany the demineralization of surface water, but we certainly have not taken the passive position of Bacon and Lewis of single acceptance of a high rate of resin replacement. We do not agree with the disarmingly simple theses of Heidorn, Reents and Thompson that tannins and lignins are the foulants and that they are readily removable by adequate coagulation—filtration. . .Much work is necessary to characterize the organic foulants in water, to remove them in pretreatment, and to remove them from fouled resins. Accepted solutions to these fouling problems will be found only if we continue to search. We have presented herein material intended to encourage others to explore and to either confirm or differ strongly with us, but above all to explore and to speak up."

Stress Corrosion

"The General Aspects of Stress Corrosion Cracking" was the general background paper provided by **Julius J. Harwood,** Metallurgy Branch Office of Naval Research, Dept. of Navy, for a full morning panel on the subject of stress corrosion.

In brief, Mr. Harwood covered so vast an area in such rapid generalities we found it most difficult to select the essentials the program planners apparently felt would be helpful in understanding the panel.

Mr. Harwood began by mentioning the increasing concern in understanding stress corrosion. This concern was confined in the 1940's to aluminum and aircraft metals. Since that time, however, the growth in variety of alloy metal suffering from stress corrosion failures as well as the number of structural failures has made this subject one of industry-wide interest. The difficulties apparently develop when we depart from the pure metals.

Pure metals, Mr. Harwood assured us, do not crack. When impurities exist or we go to alloying them the material is changed enough so heterogeneous conditions are present and stress corrosion may or may not develop. The environment under which the new metal is fabricated or employed combined with the presence of tensile stresses and stress corrosion difficulties can occur.

Attempts are being pushed to reach agreement on how corrosion develops and further on why it propagates. There is no single detailed mechanism which can be isolated as the source or the culprit. At one time Mr. Harwood expressed stress corrosion as being the interaction of chemical reactions and chemical forces to establish a brittle or mechanical type of cracking of otherwise ductile materials. This is a two-step process which is distinct for individual materials and influenced by different factors depending upon environment and surface conditions. In general, though, these two steps are the nucleation stage and the cracking stage. Much of this was covered in a Stress Conference conducted in Pittsburgh earlier in the year.

The more or less familiar corrosion control attempts of cathodic protection was discussed and its continuing value when used properly was cited. The author further suggested putting metal members in compression during the fabrication stage but certainly doing everything possible to relieve residual stresses. In addition he made passing reference to the somewhat limited success of inhibitors and various sacrificial metals.

There are at present two rather distinct schools of thought in explaining how corrosion propagates and hence how to direct research programs to combat it. The one feels the cracks propagate along purely electrochemical means and hence the corrosion once underway controls and advances the crack's progress. The second school feels this action is a combination of electrochemical and mechanical.

E. H. Phelps, U. S. Corp., presented the story of "Stress Corrosion of Ferrous Materials." He confined his comments to those steels other than the austenitic. The earliest occurrence of stress corrosion was the originally identified "caustic embrittlement" problems of the water treatment specialists.

Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion Ltd., London, W.C. 1)

Fuels: Sources, Properties and Preparation

Coal-Ash Slags. Pt. II. Flow Properties. J. T. Shaw. *B.C.U.R.A. Monthly Bull.* 1959, **23** (May) 169–90.

The second part of the review deals with: 1. Correlation between flow phenomena in the plant and laboratory measurements of apparent viscosity; 2. Correlation between flow phenomena in the plant and the chemical composition of the slag or of the slag-forming mineral matter in the coal feed; 3. Correlation between flow phenomena in the plant and the results from simple tests on ash prepared from the coal feed; 4. Summary and conclusions.

The Chemistry of Carbonization, Investigated on Polymeric Model Substances of Bituminous Coal. II. Studies of the Structure by Means of Radioactive Carbon. P. M. J. Wolfs, D. W. van Krevelen and H. I. Watermann. *BrennstChemie* 1959, **40** (June) 189–94 (in German).

To characterize polymeric structures the term "Polymerization Intensity" has been introduced; this is the number of bridges per monomeric structure unit present in the molecule. The use of radioactive carbon to facilitate the measurements and the results obtained are described.

Coal Handling Facilities at a Power Generating Station. J. Moskowitz. *A.S.M.E. Preprint* No. 59-MH-1 1959, (June) 9 pp.

The principal features of the layout of the plant for handling 1200 ton/hr of coal at the Eddystone station are described including: 1. Plant arrangement; 2. Coal conveying system; 3. Automatic operation; 4. Novel features; 5. Sampling system; 6. Car thawing facilities; 7. Dust control; 8. Mobile equipment; 9. Storage piles.

Automatic Pneumatic Handling Speeds Fly-Ash to Market. Anon. *Electr. Wrld.* 1959, **151** (June 8) 58–9.

At Sewaren station the hoppers of the electromechanical dust separators are emptied every 8 hours, a rotary feeder passing the dust into a bulk flow conveyor. This discharges into the receiving hopper of a fluidizing pump connected by pipe line to an ash rejection tank or to two silos, a 360-ton silo for bulk delivery and a 20-ton silo for filling 50-lb bags. In 1957 4100 tons were sold, mostly as additive to concrete.

One of the Nation's Largest Coal Handling Systems at New Memphis Power Plant. Anon. *Link-Belt News* 1959, **26** (April/May) 1–3.

The coal handling plant for the T. H. Allan power station at Memphis (3 × 250 MW units) has a design capacity of 2200 ton/hr. At the barge unloading tower twin 12-ton buckets can unload two 1500-ton barges simultaneously into hoppers from which four 60-in. belt feeders deliver the coal to two 48-in. belt conveyors. These transport the coal to the transfer tower for delivery to

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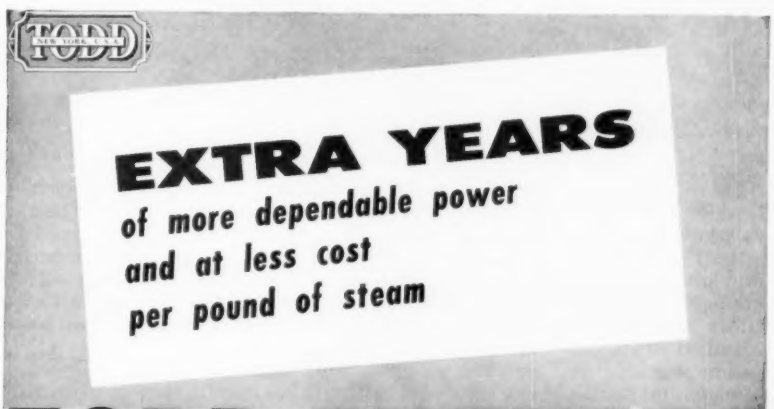

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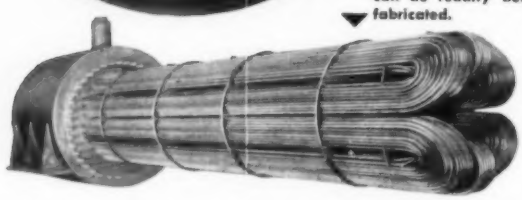

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either the storage area or the crusher house and boiler house bunkers. Samples of coal are taken in the transfer ower. The whole coal handling system is controlled by one man from the control room in the transfer tower.

Steam Generation and Power Production

A New Equation for C_p° of Steam. R. I. Aptym. *Zh. tekh. Fiz.* 1959, **29** No. 3, 307–8 (in Russian).

Both steam tables, those of Prof. Vukalovich and those of the Institute of Heat Technology, are based on the values of the specific heat of steam in the ideal-gas state calculated from spectroscopic data, and are affected by errors up to 0.3 and 0.43 per cent. New, and more accurate values of C_p° are obtained by a formula based on an interpolation method. This formula has a maximum error of 0.05 per cent in the temperature range 300 to 1100 K.

From C.E.G.B. Digest 1959, **11** (June 20) 1509.

Measurement of the Heat Losses of Insulated Steam Pipe Lines. H. Kuhn. *BWK* 1959, **11** (July) 336–41 (in German).

Investigations have shown that the measurement of the temperature drop is the best means of assessing the quality of the insulation since in this way the total heat loss can be determined while in direct heat flow measurements the losses due to spacers and supports are not included. It is recommended to obtain for the insulation of steam pipe lines an average total heat transfer coefficient which takes into account all heat losses and which can be calculated with sufficient accuracy from the measured temperature drop. The calculation of the temperature drop and the heat transfer coefficient are presented.

Tasks of Planning and Design of Future Steam Generators. J. Hegemann. *Tech. Mitt.* 1959, **52** (May) 159–69 (in German).

After discussing the application of supercritical pressures and temperatures above 1100 F in future power station boilers and the availability of steels for these steam parameters the difficulties of low load operation (20 per cent of full load) of boilers with natural, controlled and forced circulation are considered. For larger sizes and advanced steam conditions only the forced flow, once-through types of Benson and Sulzer design are available and the main problem is to ensure sufficient flow velocity at low loads to avoid film evaporation without excessive pressure drop at full load. Various possibilities of achiev-

ing this are illustrated. Recent developments of reducing losses during starting from hot or cold are also presented.

The Stabilization of Flow Distribution in Forced Flow Heating Surfaces. P. Profos. *Energie* 1959, **11** (June) 241–7 (in German).

The equations are presented for calculating when and when not uniformity of flow in forced flow heating surfaces can be expected and the necessary stability criteria are developed. Measures of artificially creating stability are discussed and the practical applicability of the stability theory demonstrated.

Gas Recirculation and Its Relation to Boiler Design and Operation. J. D. Andrew, A. M. Frendberg and P. M. Koch. *Combustion* 1959, **30** (June) 38–44.

The thermodynamic effect of gas recirculation on boiler design and operation is considered and the advantages of this system for the control of the superheated and reheated steam temperatures set out. Examples of application are described.

About Boiler Design for a Block Installation of 300 MW, 300 atü and 650°C. V. M. Biman and K. A. Rakov. *Teploenergetika* 1959 (July) 46–55 (in Russian).

Various designs are discussed for a boiler rated at 800 t/h, 310 atü and 655 C with reheat at 60 atü to 570 C and at 14 atü to 570 C and a feedwater temperature of 275 C.

Operating Conditions of Radiant Superheater arranged along the Whole Height of the Furnace. I. E. Semenovker. *Teploenergetika* 1959 (July) 41–5 (in Russian).

Data are presented of the temperature conditions of tubes and temperature characteristics of the radiant wall superheater under a steam pressure of 105 atm during steady-state and transient boiler operating conditions.

Furnace and Flue Gas Measurements in Large Brown Coal Fired Boilers. H. Trenkler. *Mitt. V. G. B.* No. 60, 1959 (June) 135–59 (in German).

The first part describes the instruments used for measuring temperatures (suction pyrometer), gas composition (combination for CO_2 + SO_2, O_2, CO and H_2), dust content of flue gas, gas velocity and volume of pulverized coal to burners. The second part describes actual measurements on two 175 ton/hr boilers, one with usual p.f. firing and the other with vent gas separation, presents and discusses the results: 1. Behavior of mills and burners; 2. Air balance; 3. Ash balance; 4.

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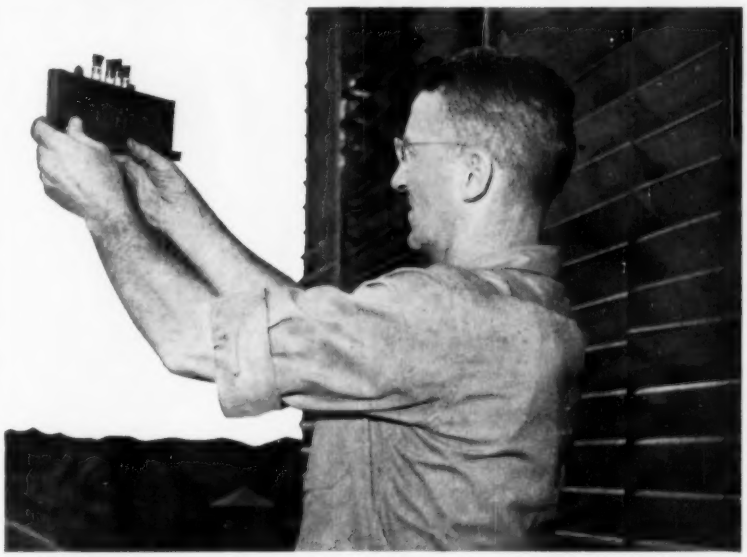

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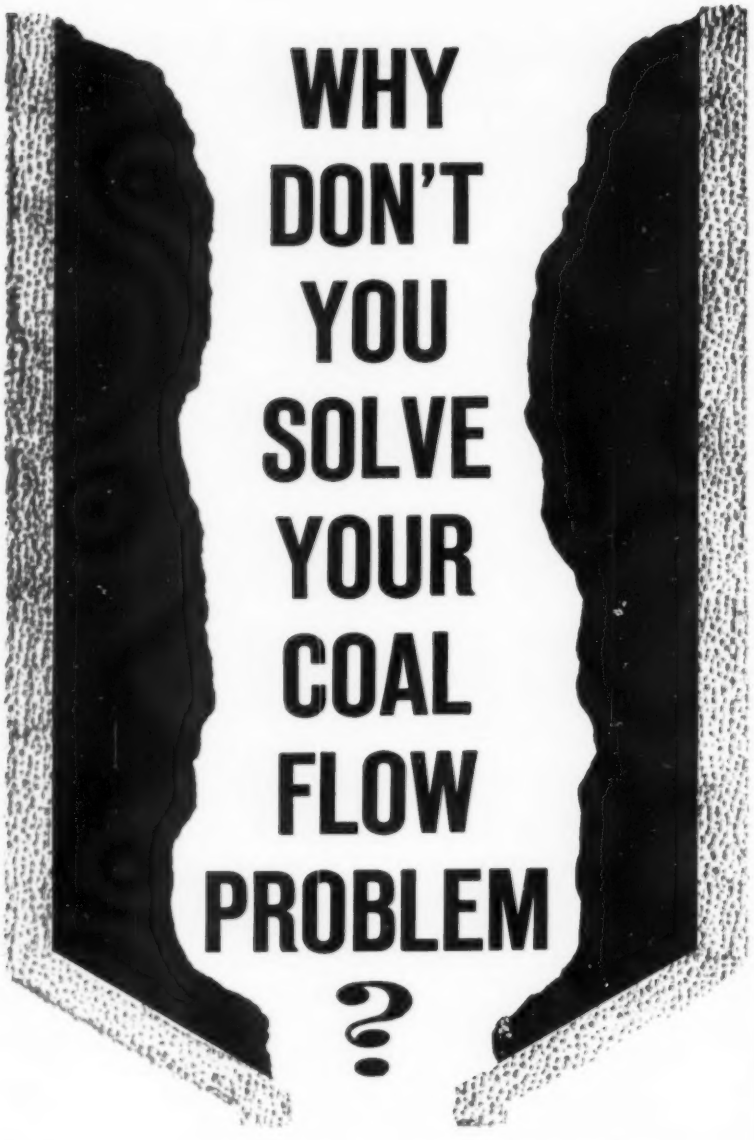

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Temperature distribution; 5. State of gas in furnace; 6. Comparison. The third part deals with similar measurements on a 450 ton/hr boiler with roof burners.

Flow Phenomena in Boiler Furnaces. H. Ullrich. BWK 1959, **11** (June) 280–3 (in German).

The contribution of molecular exchange and turbulence to flow phenomena is considered and the occurrence of eddies in furnaces with front, corner and roof burners discussed with regard to obtaining uniform temperatures over the cross-section at the furnace exit. The second part deals with the expansion of free jets in a furnace and presents results of the author's work in this field.

Gas-Side Corrosion and Deposits

Corrosion on the Flue Gas Side. Pt. I. Oil-Fired Plants. W. Gumz. *BWK* 1959, **11** (June) 284–92 (in German).

Abstracts are presented of 83 articles collected from international sources.

Corrosion on the Flue Gas Side. Pt. II. Coal-Fired Plants. W. Gumz. *BWK* 1959, **11** (July) 321–5 (in German).

An annotated review of the international literature of recent years.

Influence of Raw Material on the Fouling of Boiler Heating Surfaces. H. Kirsch. *Mitt. V.G.B.* No. 60, 1959 (June) 166–72 (in German).

The minerals occurring in Ruhr coals and their percentage composition are presented and the conversion taking place in the furnace is discussed. Studies have been made of the role of the water vapor and its influence on the volatility of various minerals, the reactions on the heating surfaces and especially those of the water-soluble alkali.

The Behavior of the Inorganic Constituents of Fuel Oils in Furnaces of Steam Generators and in Gas Turbines. K. Wickert. *BWK* 1959, **11** (June) 266–83 (in German).

The results of detailed investigations into the melting, adherence and solidification of synthetic and actual oil ashes as a function of their composition, atmosphere and temperature are presented. In particular the behavior of V_2O_5 in mixtures with $NaSO_4$, Al_2O_3, MgO, $Na_2S_2O_7$ and SiO_2 was studied. Other investigations concerned the corrosion of austenitic Cr-Ni steel by oil ash and its inhibition by addition of SiO_2 the volatility of V_2O_5 in the presence and absence of water vapor, the increased rate of oxidation of SO_2 to SO_3 in the

presence of various catalysts (pure V_2O_5, V_2O_5-Na_2SO_4, V_2O_5-Na_2SO_4-SiO_2 and $CaSO_4$ $2H_2O$ V_2O_5-fly ash, deposits on tubes of oil-fired boilers) and the treatment of residual and fuel oils to make them suitable for use in gas turbines and boilers.

Heat Recovery Plant

Aluminum Condenser Tubes Win Out at Wisconsin Electric Power. W. A. Pollock. *Pwr. Engng.* 1959, **63** (June) 74–6.

Experience with Al tubes in the condensers of No. 3 and 4 units of Oak Creek stations has been entirely satisfactory while their use in low pressure extraction heaters has not been so good due to the build up of aluminum oxide and iron oxide fouling and is therefore not recommended.

The Influence of the Water Entry Temperature on the Stability of Flow in Forced Flow Evaporators. E. Jukowsky. *Energietechnik* 1959, **9** (June) 276–8 (in German).

A mathematical analysis resulting in an equation by which it is possible to establish quickly the conditions in which instability may or may not occur in a given plant.

The Decrease of CO_2 in a Ljungström Air Preheater. W. Büttner. *Energie* 1959, **11** (June) 248–51 (in German).

The tests carried out on a modern rotary air preheater showed that the percentage decrease varied between 0.9 and 1.4 under different conditions of operation.

Power Generation and Power Plant

Pressure-Fired Cyclone Furnaces Work Well. L. W. Hoffman. *Electr. Wrld.* 1959, **151** (May 11) 48–9, 90.

Each of the two boilers at Rock River station is rated at 525 klb/h at 1500 psi and 1005/1005 F and equipped with three horizontal cyclones firing coal crushed and pulverized to 95 per cent through 100 mesh. The analysis of the coals fired varied between 7.46 and 15.92 per cent moisture, 6 and 8.5 per cent ash, 3.4 and 2.95 per cent S, 32.66 and 38.75 per cent V.M. and ash softening temperature of 2180 and 2360 F. When burning coal with ash softening temperature above 2700 F and 25 per cent of full load with a single cyclone in operation freezing of slag in the primary furnace occurred which was removed by short-time increase of load to 40 per cent. About 85 per cent of ash is retained as slag. Deposits on superheater and reheater tubes has been low, air preheaters are washed during operation by shutting down one half. Auxili-

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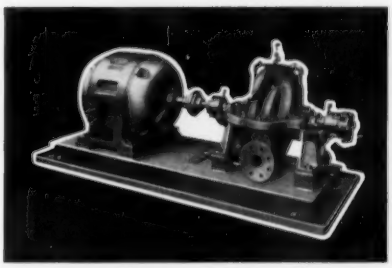

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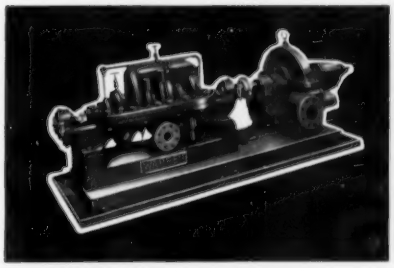

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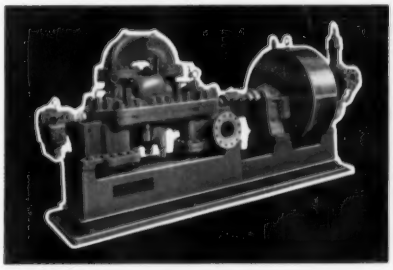

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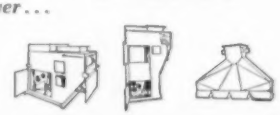

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ary power consumption was 6½ per cent at 70 per cent load and under 6 per cent at full load. Boiler efficiency was 91 per cent, availability 96.4–98.3 per cent (including yearly inspection). Station efficiency was 34.74 per cent and net heat rate 9823 Btu/kwh.

TVA Builds 500-MW Steam Unit, Largest Yet Ordered in U.S.A. R. M. Gardner. *Electr. Wrld.* 1959, **151** (May 18) 70–2, 116.

Unit No. 7 at Widows Creek station to be completed in 1960 will consist of a twin-furnance, controlled circulation, boiler rated at 3850 klb/h at 1053/1003 F and 2450 psi and a 500 MW (2 × 250 MW) cross-compound, double-flow turbogenerator (one part running at 3600, the other at 1800 rpm.). Each furnace is equipped with 5 tilting, tangentially firing burners in each corner consuming 204 t/h at full load, has a heat release rate of 11,000 Btu/cu ft and h and 52 steam operated wall blowers and 16 retractable blowers. The boiler feedpumps are turbine-driven. The electrostatic precipitators have an efficiency of 90 per cent. Feedwater is treated with sodium zeolite with hydrazine and ammonia for oxygen scavenging and pH control. The plant net heat rate is calculated to be 8913 Btu/kwh.

Boiler Plant for a Commercial Vehicle Assembly Works. Anon. *Engng. Boil. Ho. Rev.* 1959, **74** (June) 182–5.

At the new works of Commer Cars Ltd. space heating by high pressure hot water has been adopted with a circulation of 60,000 gal./h of water at 360 F. This is generated in 2 La Mont boilers, one rated at 20 mill Btu/h and the other at 40 mill Btu/h operating under a nitrogen pressure of 220 psi. The boilers are of the forced and controlled circulation type and fired with 3500-sec oil through burners of the pressure-jet type. Two vertical smoke-tube boilers at 3000 lb/h capacity each have been installed to generate steam at 100 psi to maintain the oil in the tanks at a temperature of 90 F and in the pump lines at 250/280 F which are additionally fitted with electric tracers.

How Long-Range Plans Trim Power Costs. P. L. Nelson. *Power* 1959, **103** (June) 71–4.

An outline is presented of the difficulties experienced and solutions adopted at the St. Croix Paper Co.'s plant owing to expansion of the plant and increasing unbalance of steam and electric power requirements. For the provision of more electric power a new unit consisting of a cyclone-fired boiler rated at 125 klb/h at 875 psi and 900 F and a 12.5 MW condensing turbogenerator were installed and the new paper machine is being driven by a turbine supplied from the existing 400 psi steam mains

and discharging into the 30 psi steam mains.

Chapelcross: Commissioning the First Reactor. D. R. R. Fair. *Nucl. Pwr.* 1959, **4** (June) 104–9.

The report of the commissioning deals with: 1. Training of personnel; 2. Use of plant manuals; 3. Commissioning of the plant (reactor, measurement round the critical size, calibration of control rods, hot gas circuit and burst cartridge detection, reactor to power); 4. Power plant commissioning.

Instruments and Controls

Constant Temperature Corrosion Probe. R. W. Kear. *J. Inst. Fuel* 1959, **32** (June) 267–73.

A water-cooled corrosion probe is described which requires the minimum of service and attention. The results obtained with this instrument and its scope are discussed.

Instrumentation and Automation. G. Budnick. *Progressus* 1959, **40** (E2) 37–52.

A survey of recent German developments of automatic indicating and recording instruments, continuous automatic data scanning equipment, computers and complete control systems.

Instrumentation and Computation. Anon. *Electr. Rev.* 1959, **164** (June 5) 1051–2.

Brief abstracts are presented of papers read at a conference in London in May 1959 dealing with possibilities of improving process efficiencies, process control systems and application of computers to a wide variety of purposes.

Some Recent Instruments for Measuring Gas Temperature and Heat Flow. G. G. Thurlow. *B.C.U.R.A. Bull.* 1959, **23** (April) 129–37.

Developments in suction pyrometers, venturi pneumatic pyrometers, heat flow meters and radiation meters are reviewed.

Nuclear Reactor Controls. J. Walker. *Engineering* 1959, **187** (May 22) 686–8.

The controls required for various types of reactor and the selection of the most appropriate system are discussed under the headings: 1. Control variables; 2. Reactivity balance; 3. Reactivity control methods; 4. Rate of reactivity control; 5. Range of measurement; 6. Other requirements; 7. Protection circuits.

Electronic Instrumentation for Nuclear Power Plants. C. W. Cawthorne *Nucl. Engng.* 1959, **4** (June) 263–5.

The electrical transmission of signals from conventional instruments measuring pressures, temperatures, flows, evels, densities and positions is de-

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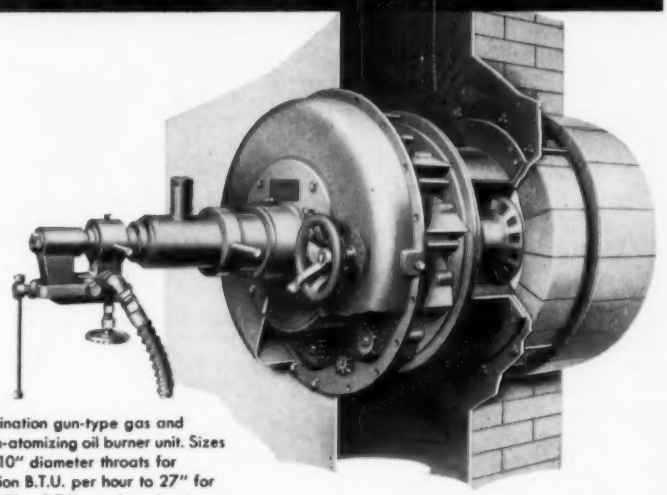

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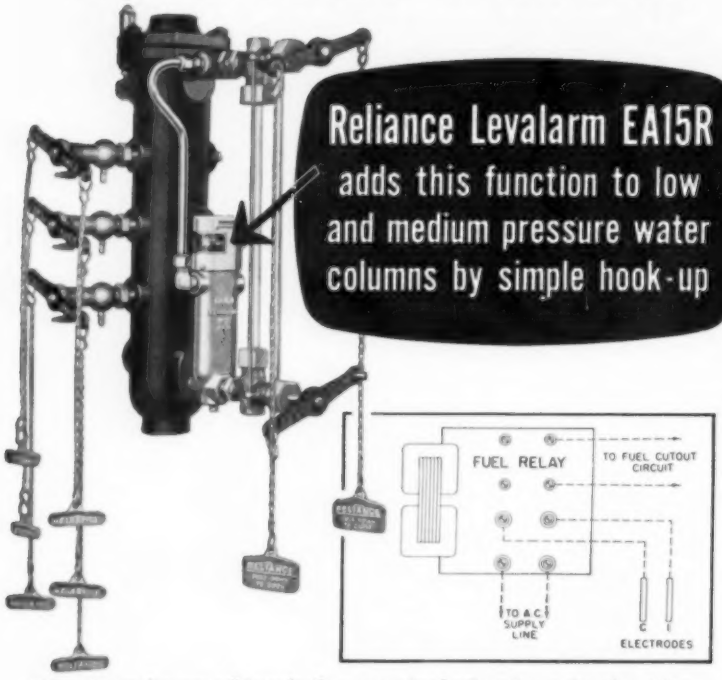
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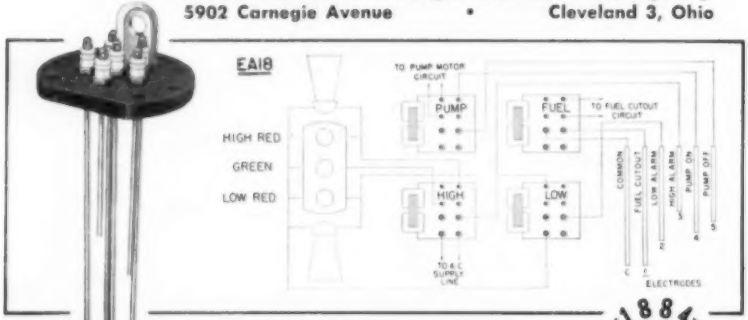

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scribed. Indicating and recording instruments and their mechanisms are briefly outlined.

Instrumentation at Nuclear Power Stations. D. Taylor. *Engineering* 1959, **187** (June 5) 750–1.

Instruments developed for the detection of burst fuel elements, measurement of the neutron flux distribution throughout the core and "in-core" neutron detection are described.

Controlling Instabilities in Graphite Power Reactors. F. G. Tyror. *Nucl. Pwr.* 1959, **4** (June) 94–7, 124.

The effect of temperature and xenon poisoning on the stability of a reactor is described and the design of a control system taking account of these effects is discussed.

Industrial pH Measurement and Control. R. S. Evans. *Electr. Rev.* 1959, **164** (June 12) 1114–7.

A review of recent developments of pH meters and control installations and their applications in various industrial processes including water treatment.

X-Ray Fluorescence Spectroscopy. C. E. Melish. *Research* 1959, **12** (June) 212–7.

In the apparatus described the X-ray tube is replaced by a radioactive source and the spectrometer by a proportional or scintillating counter. Its application is discussed.

Centralized Instruments Cut Costs, Simplify Water Treatment Control. J. C. Booser. *Power* 1959, **103** (June) 85–7.

In modern steam generating installations the number of instruments for the supervision of the feedwater has become so large that it appears necessary to centralize their location at a single point. Examples of such centralized instrument installation comprising electrical-conductivity meters, pH meters, dissolved oxygen recorders and hydrogen recorders are described.

Nuclear Energy

American Nuclear Engineering Conference. Anon. *Engineer* 1959, **207** (May 15) 785–7, (May 22) 825–7, (May 29) 865–7, (June 5) 903–5.

At the 5th Nuclear Engineering and Science Conference held in Cleveland, Ohio, a comprehensive picture was presented of the development of research and power reactors in the U.S.A. Illustrations show several of the larger nuclear power plants under construction which are briefly described, sodium-cooled, fast breeder, fluid fuel, gas-cooled, heavy water and maritime reactors, and developments in fuel elements.

Controlled Thermonuclear Reactions.

Sir John Cockroft. *Atom* 1959, (June) 12–16, 35.

After briefly outlining the reactions of interest in thermonuclear processes and the nature of the radiation loss, pinched discharge in a Torus, Zeta modifications, the Stellarator, mirror machines, Scylla, D.C.X. machine and Ogra are described.

Atomic Review, Gas Cooling Goes Abroad. Anon. *Engineering* 1959, **187** (June 5) 734–5.

Brief details and tabulated information are given of various American design studies for gas-cooled reactors: 1. Six Kaiser-ACF proposals; 2. Comparsion of enriched and natural uranium reactors; 3. KE-ACF helium cooled reactor; 4. ORNL gas cooling reactor; 5. High temperature pebble bed reactor; 6. Reciprocating gas engine reactor system; 7. Nuclear gas turbine ship; 8. Gas-cooled reactor for West Germany; 9. Russian gaseous fuel reactor.

Thermal-Resistance Concept Aids Fuel-Temperature Calculations. W. M. Rohsenow, J. P. Barger and J. Lewins. *Nucleonics* 1959, **17** (May) 150, 152, 154.

A convenient way of calculating the temperature distribution in a fuel element has been worked out if heat flux, mass flow rate and physical properties of the unit fuel cell are given.

A New Concept in Power Plants. A. P. Fraas. *Nucl. Pwr.* 1959, **4** (June) 118–9.

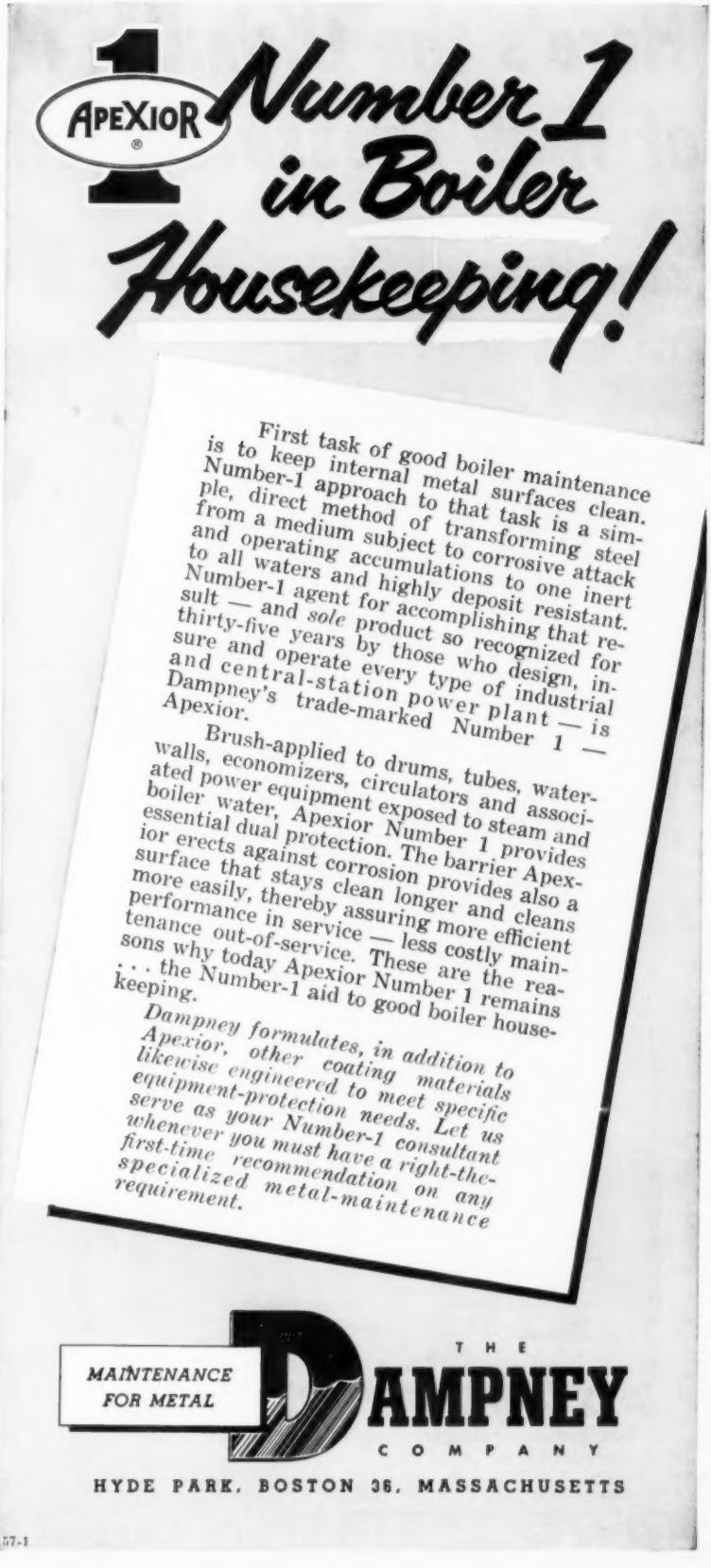
The design of a gas-cooled reactor and a reciprocating engine for ship propulsion is outlined. The reactor output would be 60 MW and the shaft horsepower 20,22000; the gas at the reactor inlet at a temperature of 600 F and at the outlet at 1100 F and a pressure of 1500 psi; the efficiency of the cycle about 3 per cent. The name given to this project is NGE-1.

A Status Report on S D R. E. Bernsohn, J. Duffy, C. K. Leeper and M. S. Silberstein. *Nucleonics* 1959, **17** (May) 112–5.

The design of a reactor using water as moderator and sodium as coolant is described which is based on experiments carried out previously. It is believed that a plant of over 40 MW size would achieve good economies.

Progress Report on Solid Fuels. Anon. *Nucleonics* 1959, **17** (May) 100–3.

A summary is presented of papers to the Symposium held at Columbia University in January. Developments in high temperature fuels, cladding and matrix materials, low-temperature fuels, fuel-cycle costs, fuel design, fabrication and reprocessing are discussed.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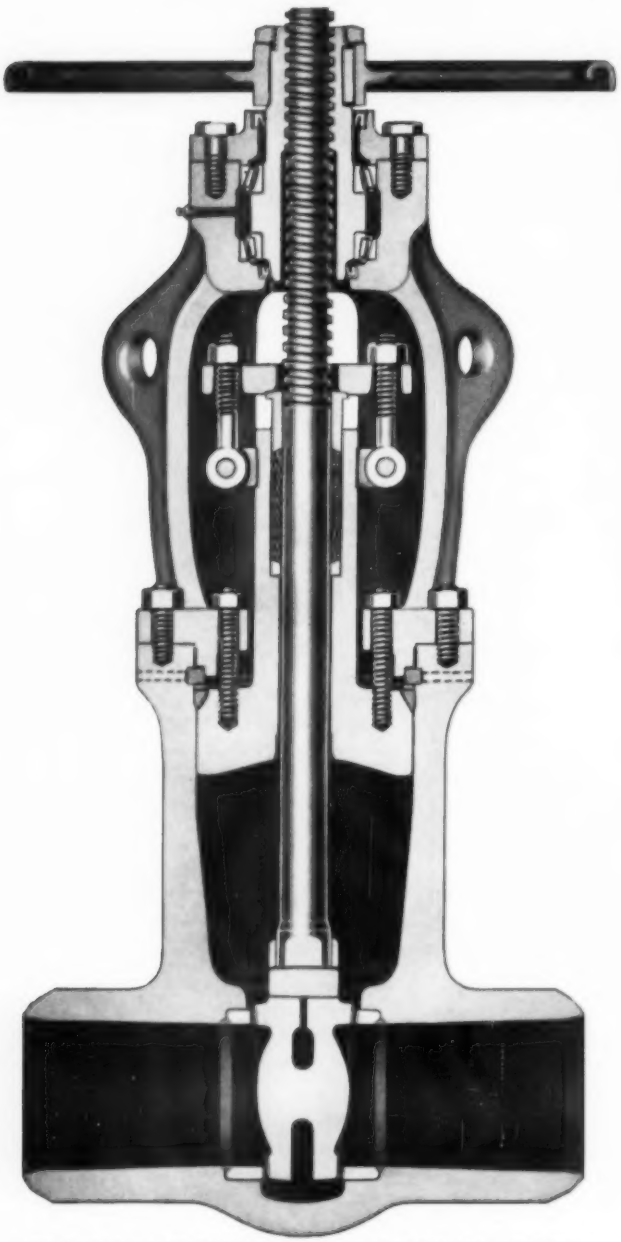

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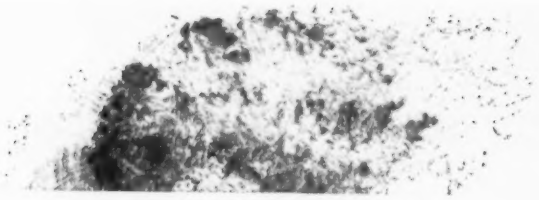

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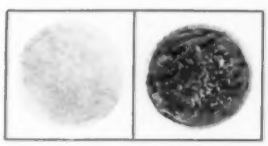

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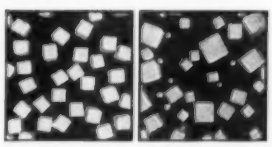

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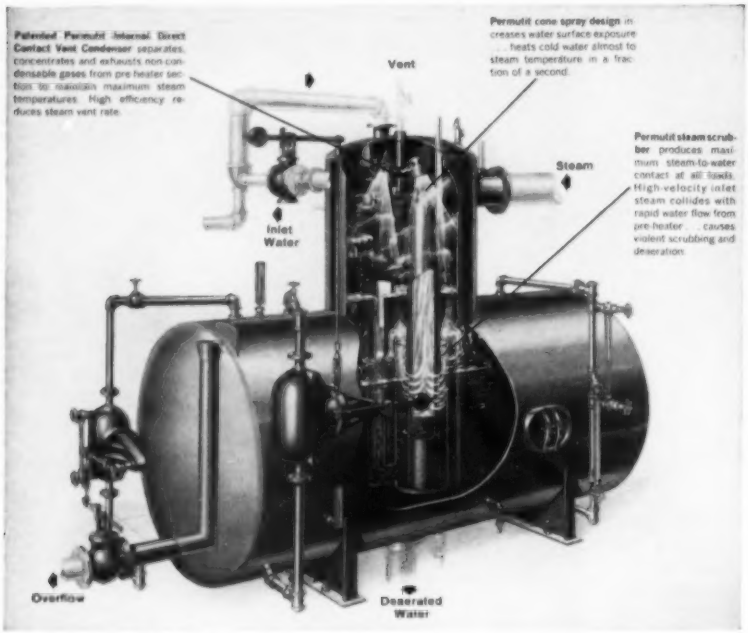
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Air Preheater Corporation, The 26
American Brass Company.... 4
American-Standard Industrial Division..... 67

Bailey Meter Company..... 10
Baltimore & Ohio Railroad.... *
Bayer Company, The..... *
Bird-Archer Company..... 59
Bituminous Coal Institute.... *
Buell Engineering Company, Inc..... 32
Buffalo Forge Company..... 19

Cambridge Instrument Company..... *
Champion Rivet Co., The..... *
Clarage Fan Company..... 72
Combustion Engineering, Inc. .....Second Cover, 16 and 17
Cooper-Bessemer.....24 and 25
Copes-Vulcan Div., Blaw-Knox Company.....20 and 21
Crane Co..... 9
Curtiss Wright Corporation, Metals Processing Div..... *

Dampney Company, The..... .....65 and Third Cover
De Laval Steam Turbine Company..... *
Diamond Power Specialty Corporation.....14 and 15
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Eastern Gas & Fuel Associates *
Edward Valves, Inc.....22 and 23
Engineer Co., The..... 63

Fairmount Chemical Co..... *
Fly Ash Arrestor Corporation. *
J. H. France Refractories Co. *

Gerotor May Corporation..... 60
Graver Water Conditioning Company..... 8
Green Fuel Economizer Company, Inc., The..... 2

Hagan Chemicals & Controls, Inc..... 28
Hall Laboratories, Div. of Hagan Chemicals & Controls, Inc..... 18
Harbison-Walker Refractories Company..... *
Haskins-Turner Company..... *
Heyl & Patterson Inc..... *

(Continued on page 71)

Illinois Water Treatment Co.. *
Ingersoll-Rand Company..... 31

Johns-Manville..... *

M. W. Kellogg Company, The. 13
Koppers Company, The..... *
Leeds & Northrup Company.. 30
Leslie Co..... 69

Manning, Maxwell & Moore, Inc..... 12
Maryland Shipbuilding & Drydock Company..... *
W. K. Mitchell & Company.... *
Morton Salt Company..... 68

Nalco Chemical Company.... 27

Peabody Engineering Corporation..... *
Pennsylvania Crusher Div., Bath Iron Works Corp..... 11
Pfaudler Permutit, Inc..... 70
Pittsburgh Piping & Equipment Company..... *
Powell Valves..... 66

Refractory & Insulation Corporation..... 71
Reliance Gauge Column Company..... 64
Republic Flow Meters Company..... *
Republic Steel Corporation.... *
Research-Cottrell, Inc..... *
Richardson Scale Company... 62
Rohm & Haas Company..... *

Standard Tube Co., The and Michigan Steel Tube Products Div..... 58
Stock Equipment Company 6 and 7
Sumco Engineering, Inc..... *
Sy-Co Corporation..... *

Todd Shipyards Corp., Products Div..... 57

Unafrax Construction Co..... 57

Valley Camp Coal Co..... 29

Warren Pumps, Inc..... 61
Western Precipitation Corporation.....Fourth Cover
Westinghouse Electric Corp., Sturtevant Div..... *

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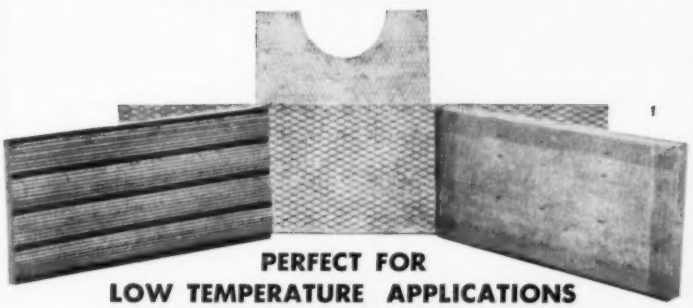

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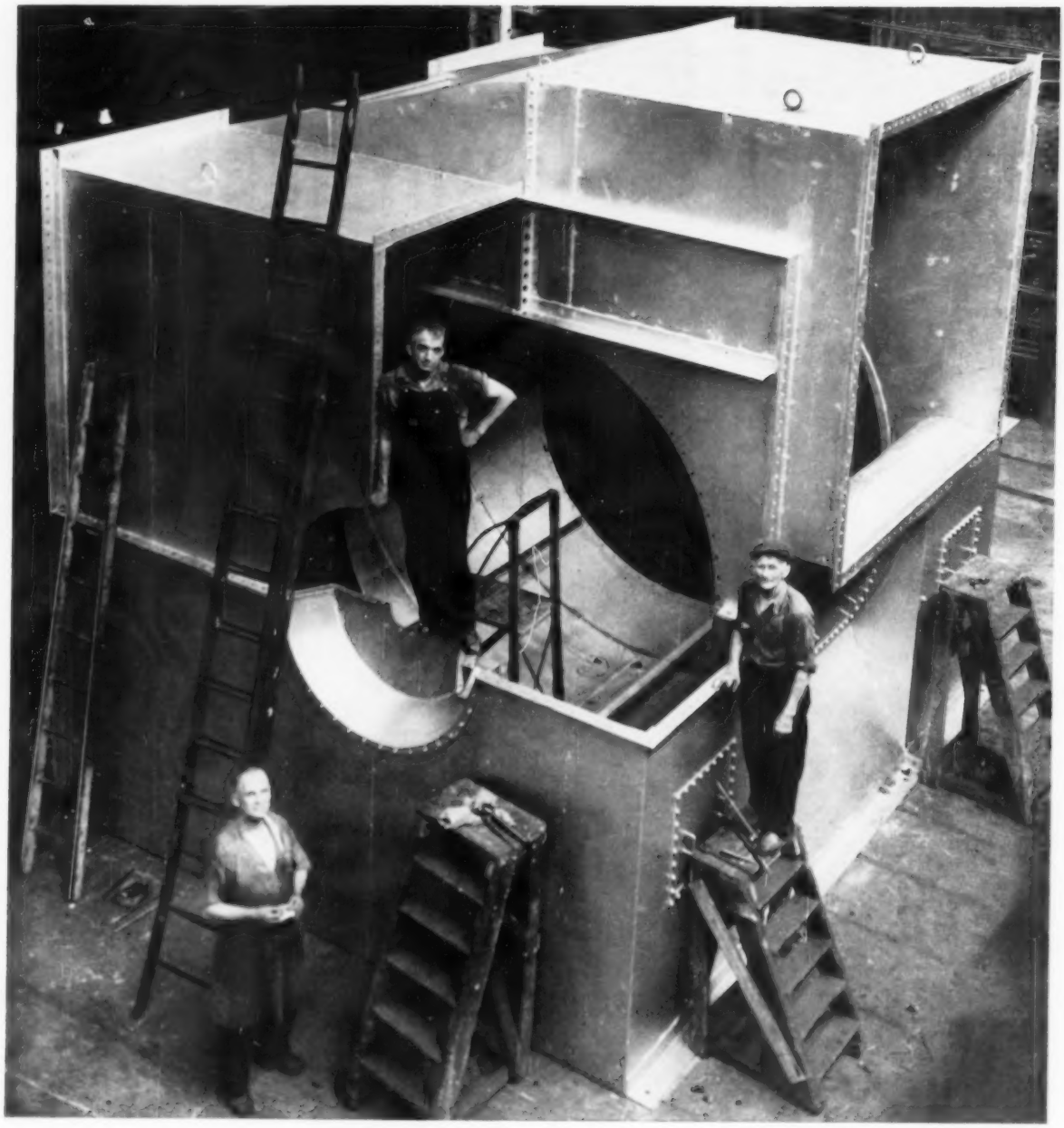

You wouldn't buy a bargain basement parachute... or a cut-rate big game rifle...

Don't choose less than Clarage quality for your mechanical draft service. With anything as vital as uninterrupted operation, it pays big dividends to get the best in equipment. Clarage, a specialist in building forced and induced draft fans, offers you equipment having a long-standing reputation for long-lasting service. CLARAGE FAN COMPANY, Kalamazoo, Michigan.

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True measure of a high-heat coating's worth is *continuous operation at rated temperature*. Yet many so-called "heat-resistant" coatings take only occasional peaks — fail rapidly in 'round-the-clock service.

Dampney coatings are rated always for day in, day out operation at maximum temperatures. Hold them to it, if schedules call for steady heat, or let them fluctuate to ambient and back. Either way, Dampney silicones and ceramics give you full protection — with plenty in reserve.

Most important, Dampney coatings are selected to meet specific conditions of operation, temperature and corrosive environment. Thus they establish a lasting foundation easily maintained and permanently ending time-consuming and costly surface preparation.

Repeat orders — from a typical customer, 26 in 12 months for enough material to protect 1,929,000 square feet of steel — is the best evidence we have that when industry wants honest high-temperature coatings, it remembers Dampney silicones and ceramics, identified by the two trade names, DAMPNEY and THUR-MA-LOX.

We suggest you do likewise when you want real protection — resistant to 1000°F., to atmospheric corrosion, and to weather exposure — for these industrial hot spots . . .

stacks and breechings	turbine interiors
steam lines	precipitators
kilns	coke ovens
forced and induced draft fans	incinerators
heat-treating furnaces	pulverizers
autoclaves and retorts	blast and open hearth furnaces

Remember, too, the first Dampney trade name and product, known and used today the world around, APEXIOR NUMBER 1 for boiler interiors. For all hot metal, wet or dry, the best protection available is made and marketed by

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That's why Western Precipitation's position in the gas cleaning field is so unique. It is the *only* organization that designs, engineers and installs *all* the basic types of gas-cleaning equipment. It is completely unbiased in its viewpoint, and is able to show you exactly how the overall costs, the collection efficiencies and the operating requirements will vary for each installation – with each type of collecting equipment that may be applicable.

Such an unbiased evaluation is invaluable in assuring optimum returns from your gas-cleaning dollar. Best of all, this unique "know-how" costs you nothing. It is a basic part of Western Precipitation's service to industry throughout the United States, Canada and the Free World.

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